IMF WORKING PAPER

WP/91/97

INTERNATIONAL MONETARY FUND

Research Department

Models of Inflation and the Costs of Disinflation

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October 1991

Abstract

This paper focuses on the output costs of disinflation. A model of inflation with both forward and backward elements seems to characterize reality. Such an inflation model is estimated using data for industrial countries, and the output costs of a disinflation path are calculated, first analytically in a simple theoretical model, then by simulation of a global, multi-region empirical model. The credibility of a preannounced path for money consistent with the lowest output loss is considered. An alternative, more credible policy may be to announce an exchange rate peg to a low inflation currency.

JEL Classification Numbers:
E31, E52

1/ The authors are grateful to Ernesto Hernández-Catá for encouraging them to work in this area, to Joseph Gagnon and Ralph Tryon for discussions of the issues, and to Charles Adams, David Coe, Steven Symansky, and seminar participants at the Reserve Bank of Australia for their comments on drafts of the paper.

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I. Introduction

It is now widely recognized that the primary objective of central banks is--or should be--the maintenance of price stability. 1/ Recent initiatives in several countries have attempted to formalize this objective: in the United States, a Congressional resolution mandating a zero inflation target for the Federal Reserve has been proposed, while in Canada, a near-term target for inflation and the ultimate goal of price stability have been announced by the Bank of Canada. 2/ In Europe, the statutes proposed for a European Central Bank state that price stability will be its primary objective. 3/ In this respect these statutes would echo the primary responsibility of the Deutsche Bundesbank, namely to safeguard the stability of the currency.

Concern to reduce inflation has made the achievement of disinflation a major macroeconomic issue of the past two decades. 4/ Reducing the rate of inflation through contractionary aggregate demand policies has in all countries been associated with a decline in output and employment relative to potential; estimates of the "sacrifice ratio" of percentage points of cumulative output loss that must be incurred in order to lower the rate of inflation by 1 percentage point range from 3 to 18 for the United States (Sachs (1985)). Yet the causes of these output losses are imperfectly understood. If nominal rigidity is due to the stickiness of the levels of wages (as in the staggered contracts models of Phelps (1978), Taylor (1979, 1980), or Calvo (1983a, 1983b)), then a path that leads to a lower rate of growth of money (as opposed to a lower level of the money supply) need not cause output losses, as long as price expectations correctly anticipate the monetary deceleration. 5/ In these circumstances, it is hard to understand why central banks could not convince the private sector that they were going to move to a money growth rate consistent with price stability, and when they did so, that wage increases would not decelerate smoothly, leaving employment unchanged. However, experience with disinflation

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1/ The goal of price stability was the focus of the policy discussion in Chapter II of the May 1990 issue of the World Economic Outlook (Washington: International Monetary Fund), which presents analysis based on a preliminary version of this paper.

2/ See Selody (1990) and Lipsey (1990) for a discussion of the issues in a Canadian context.

3/ Commission of the European Communities, "Draft Treaty Amending the Treaty Establishing the European Economic Community with a View to Achieving Economic and Monetary Union," Brussels, December 1990. EC Commission (1990) discusses the goal of price stability in a European context.

4/ We will not consider here the costs of inflation; see for instance, Chapters 1-4 of Fischer (1986).

5/ This point is made strongly by Ball (1991), who shows that a reasonably rapid credible disinflation could cause a boom in output, not output losses in a model with sticky prices (a possibility earlier raised by Fischer (1986, p. 252)).

suggests instead that there may be some fundamental stickiness in inflation rates that makes achievement of costless disinflation difficult, if not impossible. 1/

In this paper, we argue that modeling the process for inflation requires including both forward-looking and backward-looking elements. Inertia in inflation may be due to partially nonrational expectations; if expectations are adaptive, then the inflation process is purely backward looking, as in Ball (1990). In any case, a simple specification in which the two elements are present--in particular, expected future inflation and lagged inflation, with weights that sum to unity--rejects both restrictions of a unit coefficient or a zero coefficient on lagged inflation. Using this specification, we show that there is a critical value for the relative importance of the forward-looking part, above which a disinflation path with zero output losses is possible. Such a disinflation path, if it exists, implies a monotonic decline in inflation, which asymptotes to zero. The path for the money supply, however, is not monotonic.

The paper presents estimates of this inflation equation using pooled cross-section, time-series data for the industrial countries. Estimates of the forward-looking parameter are close to the threshold value mentioned above that permits costless disinflation. We then proceed to simulate various disinflation paths, using the estimated inflation equations in a global, multi-region model, MULTIMOD. These simulations imply sacrifice ratios that are positive, though below the range mentioned above. We explore the implications of changing the parameter on forward-looking behavior, by an amount suggested by the estimated standard error.

Another aspect of the disinflation problem is imperfect credibility of an announced deceleration of the money supply. Using model simulations, we illustrate how various degrees of credibility affect the output losses associated with a move to price stability. One particular feature of disinflation is that lower inflation is associated with higher money demand if money demand has a negative interest elasticity. In order not to have a decline in the price level (that is, a period of negative inflation), the money supply has to be increased at some point through an acceleration of money growth. Such a path for the money supply may strain credibility, adding to output losses. An alternative available to some countries, for instance those in the European Monetary System, may be to use an exchange rate peg to a low inflation currency as a focus for the disinflation policy, letting the path of the money supply be endogenous. We explore the implications of such a policy, compared to an imperfectly credible announced path for the money supply, accompanied by exchange rate flexibility.

1/ Ball (1990) argues that output losses are the result of adaptive expectations.

A final section advances some conclusions on the basis of our results and sketches areas for further research.

II. Price Dynamics and the Phillips Curve

Many modern macroeconomic models, and most large macro-econometric models, embody some form of the expectations-augmented Phillips curve as the basic building block describing the adjustment over time of prices (wages) to movements in aggregate demand around potential, or capacity, output (the natural rate of unemployment). The specific form of the Phillips curve implemented can play a key role in determining the short-run response to changes in policy or exogenous shocks. 1/

The dynamics of price adjustment in Keynesian models has always been a subject of considerable debate. Much of the early literature on price adjustment in these models relied either explicitly or implicitly on mistaken expectations on the part of agents in goods or labor markets and/or the ad hoc existence of asymmetrical rigidities between wages and prices. Since then various attempts have been made to develop models of disequilibrium dynamics which do not rely on expectational errors. 2/ An important and influential development has been the staggered contracts models of Phelps (1978), Taylor (1979, 1980), and Calvo (1983a, 1983b). 3/ The models emphasize the fact that wages tend to be set in nominal terms for a discrete period of time and that they are set by different agents at different points in time, that is they are asynchronous, and therefore contracts overlap. Agents are assumed to contract a wage in accordance with their anticipations of future price and output levels for the expected duration of the contract. These models typically assume that prices are a constant mark-up over wages and focus on the persistence induced in the aggregate price (average wage) level due to the asynchronous and overlapping nature of wage contracts. 4/

The staggered contracts model is consistent with various traditional reasons put forward for the existence of nominal rigidities or the

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1/ For a comparison of alternative macro-econometric models see Bryant, Henderson, Holtham, Hooper, and Symansky (1988). Obstfeld and Rogoff (1984) show how frequently used alternative price adjustment rules can alter even the qualitative response of the economy to the same shock.

2/ This is not to imply that expectational errors cannot occur in these models, in that there are unanticipated shocks to the economy. The point is rather that agents do not systematically and continuously make mistakes in the same direction, as would occur, for example, in a model with adaptive expectations when the rate of inflation permanently increases.

3/ See also Blanchard (1983) and Mussa (1981a,b).

4/ There is no presumption in this approach that formal contracts are written. Only that nominal prices (wages) are pre-set for some period of time.

incomplete adjustment of nominal prices to their equilibrium levels. A large portion of the literature on optimal price (wage) adjustment and contracting assumes a fixed, lump-sum real cost of adjustment or negotiation. 1/ This assumption has been adopted by, among others, Barro (1972), Gray (1978), and Sheshinski and Weiss (1983). Given fixed, lump-sum costs of price adjustment it will be optimal for firms in the presence of trend inflation, for example, to adjust their prices at discrete intervals of time. 2/ Romer (1990) examines the microeconomic foundations for the staggered contracts model.

This section explores the implications of alternative hypotheses about the wage-setting process and alternative assumptions on expectations formation with a view to determining the restrictions implied for the form of the Phillips curve, in particular the dependence of current inflation on past and future expected inflation. The implications of two extreme benchmark cases are considered. First, a model in the tradition of Phelps and Friedman with adaptive expectations is shown to imply a weight of unity on past inflation in determining current inflation--that is, there is complete 'inflation stickiness'--and a weight of zero on future expected inflation. Second, the Calvo (1983a, 1983b) model is shown to place a weight of unity on future expected inflation, and actual inflation is independent of the past rate of inflation--so that there is no inflation stickiness. An intermediate, alternative model and its implications for the form of the Phillips curve are then discussed: it is shown that current inflation is determined as a weighted average of past and future expected inflation.

The traditional expectations augmented Phillips curve usually posits that the rate of inflation (ΔP) equals the expected rate of inflation (Π_t^e) plus a term representing excess demand: 3/

$$\Delta P_t = \Pi_t^e + \beta y_t \tag{1}$$

1/ Again, we do not distinguish between wages and prices since this literature typically assumes that prices are a constant mark-up over wage costs.

2/ For the price quotation or 'contract' to be binding it is necessary to make additional assumptions since in a stochastic environment such contracts will typically be time inconsistent. An alternative approach is adopted by Barro (1972) and Sheshinski and Weiss (1983) who allow the 'contract' to be renegotiated when the benefits of such a renegotiation outweigh the costs. The optimal policy is an (S, s) policy, that is the price is changed when it deviates by more than a critical magnitude from the optimal or equilibrium flexible price. Parkin (1986) examines the optimality of alternative wage staggering rules.

3/ And perhaps also a term representing the change in excess demand, due to a variable mark-up of prices over unit costs.

where expected inflation is computed as a weighted average of lagged inflation rates. Assuming a geometric lag distribution,

$$\Pi_t^e = (1-\alpha) \sum_{i=0}^{\infty} \alpha^i \cdot \Delta P_{t-1-i}, \quad 0 < \alpha < 1 \tag{2}$$

which can be rewritten as

$$\Pi_t^e = \alpha \cdot \Pi_{t-1}^e + (1-\alpha) \cdot \Delta P_{t-1}. \tag{3}$$

Then substituting (3) into (1) and upon some manipulation, current inflation is given by

$$\Delta P_t = \Delta P_{t-1} + \beta(1-\alpha) y_t + \alpha\beta(y_t - y_{t-1}), \tag{4}$$

so that actual inflation equals last period's inflation plus a function of current excess demand and the acceleration in excess demand. An important implication is that current inflation can be affected only by factors that alter current excess demand. In particular, disinflation must involve output losses.

We now turn to a version of the rational staggered contracts model in discrete time. 1/ V_t is defined to be the log of the wage embodied in contracts or wage quotations initiated at time t by a representative agent, and is fixed during the length of the quotation. The quotation expiration date is assumed to be stochastic and follow a geometric distribution. It is posited that the level of the new negotiated wage is determined as a weighted average of all future price levels, P, and excess demand, y, so that

$$V_t = (1-b) \sum_{s=t}^{\infty} E_t[P_s + \beta y_s] \cdot b^{s-t} \tag{5}$$

or $$V_t = b \cdot E_t V_{t+1} + (1-b) \cdot P_t + (1-b) \cdot \beta y_t \tag{6}$$

where each period in (5) is weighted by the probability that the contract currently being negotiated will survive; E_t denotes the expectations operator conditional on information available at time t. The (log of the) average price level (which equals the log of the average wage level), P, is then defined as a weighted average of all contract wages in existence

1/ For a previous discrete-time version of the Calvo staggered contracts model see Chadha (1989).

$$P_t = (1-b) \cdot \sum_{s=-\infty}^{t} b^{t-s} \cdot V_s \qquad (7)$$

where $(1-b) \cdot b^{t-s}$ is the proportion of wages that were negotiated s periods ago. The general price level can be rewritten as a weighted average of last period's price level and the new contract wage, that is

$$P_t = b \cdot P_{t-1} + (1-b) \cdot V_t . \qquad (8)$$

The one-period-ahead expected rate of inflation (using all information available at t) can then be written alternatively as

$$E_t \Delta P_{t+1} = b \Delta P_t + (1-b)[E_t V_{t+1} - V_t] , \qquad (9)$$

or $$E_t \Delta P_{t+1} = (1-b)[E_t V_{t+1} - P_t] . \qquad (10)$$

Then, upon substitution and rearrangement the current rate of inflation can be written as

$$\Delta P_t = E_t \Delta P_{t+1} + \frac{(1-b)^2}{b} \beta y_t . \qquad (11)$$

While equation (11) resembles the traditional expectations-augmented Phillips curve posited in equation (1) with the mathematical expectation today of the rate of inflation expected to prevail tomorrow, $E_t \Delta P_{t+1}$, replacing a distributed lag over past inflation, Π_t^e, it is worth emphasizing that the difference has strong implications and will fundamentally alter the response of the economy to certain types of shocks. Note that equation (11) implies that regardless of the degree of price stickiness, as measured by the value of the parameter b, there is no stickiness in the rate of inflation. The rate of inflation is independent of the past rate of inflation and is free to jump to any value dictated by future expected inflation. The rate of inflation today will respond, therefore, to anticipated shocks that affect the rate of inflation tomorrow. This is in sharp contrast to the previous model where current inflation was tied to past inflation and could be influenced today only by contemporaneous movements in excess demand.

The two approaches represent extremes, with the traditional model of adaptive expectations implying complete inflation stickiness, and the rational staggered prices model implying no inflation stickiness. We therefore nest the two extremes in a more general model that includes both as special cases:

$$\Delta P_t = \delta E_t \Delta P_{t+1} + (1-\delta)\Delta P_{t-1} + \gamma y_t + \beta \Delta y_t \tag{12}$$

Such a generalization could be given a heuristic justification by assuming the existence of both backward and forward looking agents. Alternatively, and somewhat more formally, there are wage-setting characteristics that would lead to some inflation stickiness--and in particular, to current inflation being a weighted average of both past inflation and future expected inflation.

These characteristics may be classified as "incomplete forward looking." The traditional adaptive expectations model discussed is of course an extreme example. We now present an example to illustrate the point more generally. Suppose that wage setters set contract wages according to the rule

$$V_t = V_{t-1} + E_t \Delta P_{t+1} + \beta y_t \tag{13}$$

so that those negotiating wages today set theirs to emulate the level of wages contracted last period, adjusted to compensate for inflation expected next period, and also as a function of prevailing excess demand. Wage setters are, therefore, partly backward looking and partly forward looking, but myopically so in that they do not look at expected inflation or excess demand for the full duration of the contract. Then, again assuming that contract expiration dates are geometrically distributed, and substituting (13) into the first difference of (8) yields

$$\Delta P_t = b\Delta P_{t-1} + (1-b)E_t \Delta P_{t+1} + (1-b)\beta y_t \tag{14}$$

so that current inflation is a weighted average of past and expected future inflation.

III. The Dynamics of Disinflation

This section considers the dynamics of disinflation along a path with minimum output losses. An inflation equation with backward and forward-looking elements, as described above in equation (12), is embedded in a very simple closed-economy macro model containing equations for aggregate demand and money demand. If perfect foresight prevails, then equation (12) can be written in terms of the acceleration of inflation η_t:

$$\eta_{t+1} = [(1-\delta)/\delta]\eta_t - (\alpha/\delta)y_t - (\beta/\delta)\Delta y_t, \tag{15}$$

where $\eta_t \equiv \Delta P_t - \Delta P_{t-1}$.

The root of this equation is equal to $\lambda = (1-\delta)/\delta$, which is less than unity if and only if $\delta > 0.5$.

We combine the inflation equation with a simple aggregate demand relationship that relates the output gap y to the real interest rate,

$$y_t = \theta(i_t - \Delta P_{t+1}) \tag{16}$$

and with a money demand equation,

$$M_t - P_t = \rho y_t - \gamma i_t + \phi(M_{t-1} - P_{t-1}) \tag{17}$$

where i_t is the nominal interest rate, and M_t the log of the nominal money stock. 1/ In this model, let us consider what the dynamics of disinflation must be in order to minimize, or avoid completely, output losses. From (15), setting $y_t = 0$ gives a path for the inflation rate. This yields

$$\eta_{t+1} = \lambda\eta_t \tag{18}$$

so the rate of inflation in any future period ($t \geq 1$) is given by

1/ This model extends the model of the previous section because it makes money demand explicit and models the transmission of monetary policy through the channel of interest rates. For simplicity, we ignore the effect of trend growth in capacity output on money demand, and assume that equilibrium real interest rates are zero. These simplifications could be relaxed without changing the analysis.

$$\Delta P_t = \Delta P_0 + \eta_1 \sum_{i=0}^{t-1} \lambda^i = \Delta P_0 + \eta_1 \left[\frac{1 - \lambda^t}{1 - \lambda} \right] \tag{19}$$

Equation (19) expresses the path of inflation in terms of the initial <u>deceleration</u> of inflation, $\eta_1 < 0$, and the dynamics of the subsequent optimal disinflation, which depends on the weight on future inflation in wage determination. It is clear from (19) that convergence to zero inflation along this path requires that $\lambda < 1$, which will hold if and only if $\delta > 0.5$.

That is, zero output losses are possible in a transition to a lower inflation rate, only if δ is above 0.5, and provided the announced policy is credible. 1/ The intuition for this result is as follows: if inflation is expected to fall next period, it pulls down this period's inflation, ΔP. The key to costless disinflation is to decelerate money growth at a rate such that the fall in inflation today (relative to last period's) is just offset by the further fall expected in the following period. What this implies, in our model, is that zero inflation is approached asymptotically--there is always an extra downward drag on today's inflation rate from a further expected decline. However, provided that the forward term more than offsets the past (i.e., $\delta > 0.5$), and there is the expectation that inflation will decline in the future (i.e., the policy is credible), then the whole process of deceleration from a positive inflation rate can be set in motion with a path of decelerating money growth, without incurring output losses. 2/

Starting from an initial inflation rate ΔP_0, we can calculate the initial deceleration of inflation that is needed to achieve price stability asymptotically, provided $\lambda < 1$. From (19), it is given by

$$\lim_{t \to \infty} \Delta P_t = \Delta P_0 + \eta_1/(1-\lambda) = 0, \tag{20}$$

so

$$\eta_1 = -\Delta P_0(1-\lambda) \tag{21}$$

The closer λ is to 1, i.e., the closer δ is to 0.5, the more gradual is the initial deceleration of inflation, η_1, and also the slower is its subsequent decline, along a path with zero output losses. Of course, for estimates of

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1/ Phelps (1978) also examines zero output loss disinflation paths.

2/ If $\delta < 0.5$, then zero output losses would require ever-accelerating declines in inflation, which, however, must eventually come to a halt to prevent ΔP_t becoming unbounded in a downward direction. At this point (if not before) output losses would be incurred.

δ slightly below 0.5, costs of disinflation, though positive, will be small; output losses will increase the smaller is δ.

What does the path for the money supply look like along the optimal disinflation path? Suppose we start from a position in which output is at potential, so $y_0 = 0$, and $\Delta P_o = \Delta M_o$. Therefore, along the optimal disinflation path, $\Delta y_t = 0$, and from (16), $i_t = \Delta P_{t+1}$. If we first difference the demand for money and substitute for Δy_t and Δi_t:

$$\Delta M_t - \Delta P_t = -\gamma(\Delta P_{t+1} - \Delta P_t) + \phi(\Delta M_{t-1} - \Delta P_{t-1}) \tag{22}$$

Or, in terms of real balances ($m_t = M_t - P_t$), since $\Delta P_t = \Delta P_o \lambda^t$ on the optimal disinflation path,

$$\Delta m_t = \gamma(1 - \lambda)\Delta P_0 \lambda^t + \phi \Delta m_{t-1} \tag{23}$$

In period 1,

$$\Delta m_1 = \lambda\gamma(1 - \lambda)\Delta P_0 > 0 \tag{24}$$

so real balances increase, as do nominal balances (since $\Delta P_0 > 0$). It is clear from (23) that in subsequent periods ($t > 1$), real balances also increase.

It is also of interest to consider whether nominal balances accelerate or decelerate along the disinflation path; this depends on both the interest elasticity of money demand and the speed of adjustment of inflation. Since

$$\begin{aligned}\Delta M_1 = \Delta P_1 + \Delta m_1 &= \lambda\Delta P_0 + \lambda\gamma(1 - \lambda)\Delta P_0 \\ &= \lambda\Delta P_0[1 + \gamma(1 - \lambda)]\end{aligned} \tag{25}$$

$$\begin{aligned}\Delta M_1 - \Delta M_0 &= \lambda\Delta P_0[1 + \gamma(1-\lambda)] - \Delta P_0 \\ &= \Delta P_0(1 - \lambda)[\lambda\gamma - 1]\end{aligned} \tag{26}$$

In the first period, nominal balances accelerate if $\lambda\gamma > 1$. So here the Cagan (1963) condition emerges, though in a modified form: the rate of growth of the nominal money supply increases upon implementing a disinflation policy, if the product of the interest semi-elasticity and one minus the speed of adjustment of inflation (i.e., λ) exceeds unity. The parallel with the Cagan analysis of hyperinflation using adaptive expectations becomes clear when the path of inflation is written as a first-order equation as follows

$$\Delta P_t - \Delta P_{t-1} = (1 - \lambda)(\overline{\Delta P} - \Delta P_{t-1})$$

where $\overline{\Delta P} = 0$, the long-run rate of inflation. If $\lambda\gamma > 1$, a small fall in inflation and hence interest rates produces a large increase in the demand for real balances in period 1, which dominates the effect of a lower price level on nominal balances. In this case, the credibility of an optimal disinflation path would be doubtful, since it involves an <u>acceleration</u> of money growth initially.

What about the subsequent paths for real and nominal balances? From (23), the solution for the change in real balances can be written

$$\Delta m_t = \lambda^t \gamma(1 - \lambda)\Delta P_0 \sum_{i=0}^{t-1} (\phi/\lambda)^i \tag{27}$$

and the <u>acceleration</u> in real balances is

$$\Delta m_t - \Delta m_{t-1} = \lambda^{t-1}\gamma(1 - \lambda)\Delta P_0\{(\lambda - 1) \sum_{i=0}^{t-1} (\phi/\lambda)^i + (\phi/\lambda)^{t-1}\} \tag{28}.$$

Whether the acceleration of real balances is positive or negative depends on the sign of the term within { }. So $\Delta m_t - \Delta m_{t-1} \gtrless 0$ if

$$(1 - \lambda) \sum_{i=0}^{t-2} (\phi/\lambda)^i \lesseqgtr \lambda(\phi/\lambda)^{t-1} \tag{29}.$$

It is not in general possible to sign this expression; for some parameter values, money balances may accelerate for a time, and then decelerate. To calculate the implied path for the money supply requires parameter estimates; we now turn to estimation of the inflation equation.

IV. Estimation Results

Reflecting the discussion in Section II, we now present estimates of a general form of the inflation equation where inflation is a function of both past and future expected inflation, and of the degree of capacity utilization. Variants of the equation are estimated that incorporate a nonlinear relationship between capacity utilization and inflation, and country-specific parameters. While little support for a nonlinear capacity-utilization effect is found, there is some evidence of differences across countries in the degree of inflation stickiness. The polar cases of weights of unity on either lagged or led inflation are both strongly rejected.

1. The equation to be estimated

In addition to the lagged and led inflation terms, an absorption price term is included in estimation to allow for the potential desire of wage earners to be compensated for changes in the real consumption wage. The form of the equation that we estimate is the following:

$$\Delta P_t = \delta E_t \Delta P_{t+1} + (1-\delta)\Delta P_{t-1} + \alpha(\Delta PA_t - \Delta P_t) + \gamma(PA_t - P_t) + \beta f(CU_t) \quad (30)$$

where P_t is the logarithm of the non-oil GNP deflator in period t, PA_t is the log of the absorption deflator, CU_t is the capacity utilization rate defined to equal 100 when output is at its capacity level, and α, β, γ, and δ are parameters to be estimated. The function f(CU) is a (possibly nonlinear) function of the contemporaneous capacity utilization rate. 1/ The inclusion of either the level or the growth rate of the absorption price can be motivated by different theoretical models. The Calvo model, which specifies a fixed level for the wage over the life of a contract, implies that the relevant variable is the relative level of the absorption price. In other models, where contract wages grow over time, it is the growth rate that is relevant. Both terms have been included in equation (30) to nest these two possibilities in the initial specification.

The presence of ΔP_t and P_t on the right-hand side of equation (30) is likely to generate a negative correlation between the relative price terms and the structural disturbance: to reduce this problem, the equations were re-parameterized by adding $(\alpha+\gamma)\Delta P_t$ to each side. 2/ Dividing by $(1+\alpha+\gamma)$ then gave the following equation to be estimated:

$$\Delta P_t = (1-\tilde{\alpha}-\tilde{\gamma})[\delta E_t \Delta P_{t+1} + (1-\delta)\Delta P_{t-1}] + \tilde{\alpha}\Delta PA_t + \tilde{\gamma}(PA_t - P_{t-1}) + \tilde{\beta} f(CU) \quad (31)$$

1/ The first difference of capacity utilization did not enter significantly, so is ignored in what follows.

2/ Instrumental variables were used in estimation to control for the endogeneity of the other regressors, as discussed below.

where $\tilde{\alpha} = \alpha/(1+\alpha+\gamma)$, $\tilde{\gamma} = \gamma/(1+\alpha+\gamma)$, and $\tilde{\beta} = \beta/(1+\alpha+\gamma)$.

2. Estimation results

The initial stage of estimation involved testing equation (31), with expected inflation replaced by led inflation, against alternatives that had constraints imposed on the coefficients on future and lagged inflation and on the relative price terms. The limiting case of a zero weight on future inflation is consistent with the traditional Phelps-Friedman model with backward-looking expectations. At the other extreme, a weight of unity yields the Calvo model with fully forward-looking behavior and no inflation stickiness. A linear specification was initially used for the capacity utilization term: $f(CU) = CU/100-1$. This implies that capacity utilization exerts no pressure on inflation at a "normal" level of 100, consistent with the construction of the capacity utilization series as 100 times the ratio of actual to trend output. 1/ In the absence of a constant term in the price equation, the "natural" rate of capacity utilization then equals 100.

To control for the endogeneity of the right-hand-side variables dated period t and t+1, they were first regressed on a set of country-specific instruments consisting of: the lagged level of capacity utilization; the lagged ratio of government spending to capacity output; lagged growth in the non-oil GNP deflator; and lagged growth in real money balances. A Zellner-efficient systems estimator was then used to jointly estimate equation (31) for the G-7 countries over 1966-88, with common parameter values imposed across those countries. As preliminary results revealed large outliers in the residuals for the United Kingdom, it was excluded from the pooled sample. 2/

1/ The capacity utilization rate was constructed using a time-series filter to derive a capacity output series for each G-7 country from observed quarterly GNP data. The filter is the variant of the one developed by Hodrick and Prescott (1980), which has been used extensively to detrend economic data for the analysis of real business cycles (see, e.g., Backus and others (1989)).

2/ The problem with the U.K. data is associated with the surge in inflation from 7 percent in 1973 to over 27 percent in 1975, and the sharp decline thereafter. This surge of inflation was not related to strong economic activity--1975 was a recession year in the U.K.--but rather seems to reflect a wage-price spiral caused by attempts to recover real wage losses following the first oil price shock.

Table 1. Estimation Results for the Non-Oil GNP Deflator, Common Parameters

Equation: $\Delta P = (1-a2-a3)[a1\Delta P_{+1} + (1-a1)\Delta P_{-1}] + a2\Delta PA + a3(PA-P_{-1}) + a4(CU/100-1)$

Estimation Period: 1966-88

Estimation Technique: Iterative Zellner-efficient with instrumental variables

Estimated Parameters (absolute values of asymptotic t-ratios in parentheses):

	a1	a2	a3	a4	θ^*
1. Unconstrained	0.442 (7.6)	0.268 (3.0)	0.033 (1.4)	0.283 (2.5)	-
2. a1 constrained to 0	0	0.619 (11.6)	0.024 (1.0)	0.406 (3.4)	30.83
3. a1 constrained to 1	1	0.674 (12.0)	0.053 (1.9)	-0.043 (0.5)	33.11
4. a2 constrained to 0	0.458 (8.8)	0	0.043 (1.5)	0.353 (3.0)	9.10
5. a3 constrained to 0	0.423 (7.3)	0.306 (3.2)	0	0.285 (2.5)	0.10

* Test of the null hypothesis that the constrained model is true. θ is asymptotically distributed $\chi^2(1)$: the critical value at the 2.5 percent significance level is 5.0.

The unconstrained parameter estimates obtained from estimation of equation (31) are shown in Line 1 of Table 1. 1/ The weight on future inflation is estimated to be slightly less than 1/2; both of the terms in the absorption deflator have the expected (positive) sign; and the capacity utilization rate enters with the expected sign and its coefficient is statistically significant. Lines 2 and 3 present estimates with the parameter on future inflation constrained to 0 and 1 respectively. The modified likelihood-ratio test suggested by Gallant and Jorgenson (1979) indicates either of these limiting values for a1 is strongly rejected by the

1/ The (country-specific) constant terms were all small and insignificant in preliminary estimation: they have been constrained to zero. Estimation was also performed allowing for first-order autoregressive and moving average processes for the residuals: these coefficients were insignificant as a group and had little effect on the other parameter values, thus they were excluded in further estimation. It should be noted that the estimate of the asymptotic variance-covariance matrix of the parameters used to construct the t-ratios may not be consistent for the reasons discussed in Cumby and others (1983).

data. 1/ This suggests that the inflation process is characterized by a degree of inertia intermediate between traditional backward-looking models, at one extreme, or the Calvo model, at the other extreme. Line 4 shows the results when the coefficient on growth in the absorption deflator is constrained to 0: a likelihood-ratio test indicates that this constraint is also strongly rejected by the data. In contrast, the constraint that the parameter on the level of the absorption deflator is 0 cannot be rejected at conventional levels of significance, as shown in Line 5. The latter estimates, then, represent the preferred price equation. They were used both as the starting point for the extended estimation results discussed below, and as the basis for the model simulations presented in the next section.

3. Nonlinear capacity utilization effects

If there exists an upper limit on the achievable level of output in the short run, then the output-inflation tradeoff should become increasingly steep as this limit is approached. To test the empirical validity of this hypothesis, the equation was specified so that the degree of inflation pressure depends nonlinearly on the output gap. The functional form used was:

$$f(CU) = a3 \left[\frac{a4^2}{a4-(CU/100-1)} - a4 \right] . \tag{32}$$

The expression is parameterized so that a3 has the same interpretation as for the linear relationship when CU equals 100: specifically, inflation pressure is zero at this point, and the slope of the price-output tradeoff is equal to a3. The trade-off becomes vertical as CU/100-1 approaches a4: the latter parameter thus determines the limiting rate of capacity utilization. As a4 becomes large, the curvature of the function decreases; when a4 approaches infinity the function becomes linear. 2/ Because expression (32) is a nonlinear function of a4, a grid search was performed to identify the value that maximized the likelihood function.

Estimation results for this equation are shown in Table 2. The likelihood function reaches a maximum when a4 is about 0.08, implying that the short-run aggregate supply curve becomes vertical when output reaches 108 percent of long-run potential. The likelihood function, however, is

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1/ The test statistic is asymptotically distributed $\chi^2(n)$, where n is the number of linear constraints. It will not necessarily be positive in finite samples, as the estimates of the variance-covariance matrix of the residuals in the restricted and unrestricted models are not identical.

2/ This can be seen by calculating $d^2f(CU)/dCU^2 = a4^2/(a4-(CU/100-1))^3$. It is apparent that this expression--which indicates the change in the slope of the output-price tradeoff as CU changes--goes to zero as a4 becomes large regardless of the value of CU.

quite flat for a range of values around this level. A test of the null hypothesis that the relationship is linear (i.e., that a4 = ∞) yields a test statistic of 4.6, distributed asymptotically $\chi^2(1)$, thus the null hypothesis of a linear relationship cannot be rejected at the 2.5 percent level of significance (critical value 5.02), but it can at the 5 percent level (critical value 3.84). While the historical data provide some evidence for a nonlinear tradeoff between output and prices, it is not however strong. For the purposes of further estimation and simulation, the null hypothesis of a linear tradeoff was maintained.

Table 2. Estimation Results for the Non-Oil GNP Deflator, NonLinear Capacity Utilization Effect

Equation: $\Delta P = (1-a2)[a1\Delta P_{+1} + (1-a1)\Delta P_{-1}] + a2\ \Delta PA + a3\ [a4^2/(a4-(CU/100-1)) - a4]$

Parameters:

Imposed value for a4	a1	a2	a3	log likelihood function
0.05	0.450	0.326	0.203	517.94
0.07	0.442	0.320	0.232	520.30
0.08	0.440	0.318	0.240	520.40
0.09	0.438	0.317	0.246	520.39
0.10	0.436	0.316	0.251	520.32
0.15	0.432	0.312	0.265	519.90
0.20	0.429	0.311	0.271	519.57
∞ (Linear Specification)	0.423	0.306	0.285	518.10

4. Country-specific parameters

Finally, we tested for differences in parameters across countries. Because of a limited number of observations for each country, the six countries 1/ were grouped into three geographic regions within which the same price behavior was assumed to prevail. The regions were Europe, consisting of Germany, France, and Italy; North America, consisting of the United States and Canada; and Japan. The results are shown in Table 3 for both the unconstrained equation and several parameter constraints. In the case where all three parameters (a1, a2, and a3) differ across regions (Line 1), results for Japan were implausible, with a negative (but insignificant) weight on future inflation and a very large parameter on capacity utilization. In what follows, therefore, we have constrained a1 to be the same across regions. A likelihood-ratio test could not reject the hypothesis that they were all the same (Line 2).

Tests were then performed to see if either a2 or a3, or both, differed significantly across regions when a1 was constrained to be the same. When the parameter on absorption inflation (a2) varied across countries (Lines 2 and 4), it is apparent that the coefficient is much larger for Japan than the other regions; however, the hypothesis that a2 is the same across regions cannot be rejected at conventional significance levels. The higher

1/ As noted above, the United Kingdom was excluded.

value for Japan may reflect two factors: a greater responsiveness of contract wages to consumption prices because, for instance, of bonus payments and indexation provisions in contracts; or a shorter average contract length than for the other regions. 1/ The results shown in Line 3 indicate that the parameter on capacity utilization, a3, is also higher for Japan than the other regions, though differences are again not significant. The higher parameter on capacity utilization may reflect either greater sensitivity of new-contract wages to market conditions, or, as for a2, a shorter average contract length, implying that a higher percentage of overall wages is affected by current conditions.

Table 3: Estimation Results for the Non-Oil GNP Deflator, Region-Specific Parameters

Equation: $\Delta P = (1-a2)\ [a1\ \Delta P_{+1} + (1-a1)\ \Delta P_{-1}] + a2\ \Delta PA + a3\ (CU/100-1)$

Estimated Parameters (absolute values of asymptotic t-ratios parentheses):

	a1	a2	a3	θ^*
1. Unconstrained a1, a2, a3				
- North America	0.444 (2.3)	0.207 (1.1)	0.305 (1.1)	-
- Europe.	0.435 (7.3)	0.097 (0.6)	0.220 (1.4)	
- Japan	-0.750 (0.6)	0.312 (0.4)	3.535 (0.6)	
2. Constrained a1				
- North America	0.430 (7.9)	0.199 (1.1)	0.331 (1.9)	0.55
- Europe.	"	0.098 (0.7)	0.235 (1.7)	
- Japan	"	0.675 (5.4)	0.240 (0.9)	
3. Constrained a1 and a2				
- North America	0.390 (6.3)	0.282 (2.5)	0.324 (2.0)	1.70
- Europe.	"	"	0.196 (1.4)	
- Japan	"	"	0.752 (1.8)	
4. Constrained a1 and a3				
- North America	0.435 (8.1)	0.222 (1.4)	0.284 (2.5)	-0.14
- Europe.	"	0.095 (0.7)	"	
- Japan	"	0.662 (6.0)	"	

*Test of constrained model against the unconstrained model of Line 1. θ is asymptotically distributed $\chi^2(2)$: the critical value at the 5 percent significance level is 5.99.

To summarize, these results support an inflation equation in which current inflation depends on a weighted average of past and future expected inflation. The restrictions implied by the pure forward-looking, level models of Calvo (1983a, 1983b) and by the pure backward-looking, traditional Phillips curve models, are both convincingly rejected. The data do not

1/ Other multi-country studies of price behavior also find a greater response in Japan to market conditions. See, for instance, Grubb and others (1983) and Coe (1985).

strongly support the hypothesis of a nonlinear Phillips curve. The evidence in favor of differing parameters across countries in the price equation is inconclusive, largely because the individual parameters are not estimated precisely. The point estimates, however, suggest that the response of prices to current market conditions and to relative price movements may be greater in Japan than in the other industrial countries.

V. MULTIMOD Simulations of Disinflationary Policies

This section presents simulations of alternative disinflationary policies using MULTIMOD, a multi-region global macroeconomic model developed at the Fund. 1/ The focus is on the transitional costs in terms of lower output of reducing the inflation rate: the long-run benefits of lower inflation, such as possible reductions in relative price variability, inflation uncertainty, and distortions in tax systems, are not captured by the macroeconomic simulations. The results indicate that the output costs are transitory, and vary according to factors such as the speed with which the disinflationary policy is phased in, the credibility of the authorities' commitment to reducing inflation, the degree of forward-looking behavior in price and wage setting, and the responsiveness of prices to demand conditions. 2/ Sacrifice ratios are calculated that compare the cumulative output loss to the reduction in inflation: the implied costs of disinflation are lower than some others found in the literature. International aspects of disinflationary policies are also examined. In particular, we look at spillover effects on other countries of disinflationary policies in the United States, and also at the use of exchange-rate versus money-supply targeting to reduce inflation.

1. Simulations of disinflationary policies in the United States

The effects on real output of alternative programs that reduce the target for U.S. money growth by 4 percent per year are shown in Table 4. 3/ The reduction in target money growth was chosen to roughly represent the difference between the existing trend U.S. inflation rate and price stability: as money demand is homogeneous of degree one in prices in MULTIMOD, a 4 percent decline in money growth leads over time to a 4 percentage point decline in the inflation rate. The price equation used for the simulations is shown in Line 5 of Table 1 in the previous section,

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1/ See Masson, Symansky, and Meredith (1990).

2/ Subject to the usual caveats of the Lucas critique; in particular, the relative weight of forward and backward-looking elements in the inflation process may themselves depend on monetary policy.

3/ Monetary policy is implemented in MULTIMOD in terms of an exogenous path for the target money supply. The actual money supply can differ in the short-run from the target, as the monetary authorities are assumed to smooth the interest rate changes that would be needed to keep money on target in each period.

with common parameters across countries. The weight on future inflation is estimated to be 0.423. The simulations differ in terms of the speed with which the disinflationary policy is implemented, ranging from an immediate decline in money growth of 4 percent in 1990 (Program 1), to a phase-in over an 8-year period starting in 1991 (Program 4). In all cases except Program 3, the policy is assumed to be fully credible in the sense that future reductions in money growth are anticipated at the time the policy is announced. For Program 3, it is assumed that agents expect observed declines in money growth to continue indefinitely: as the program is phased in gradually, their expectations of future money growth are too high during the phase-in period.

In the case of Program 1, real GDP in the U.S. falls by 2.4 percent on impact and by a cumulative 7.9 percent over the first five years of the simulation. To understand the role played by price stickiness in the MULTIMOD results, it is useful to first consider those of a classical flexible-price model where output is always at potential. In this model--which corresponds to having an infinite parameter on the capacity utilization rate in the MULTIMOD price equation--the price level jumps in each period to keep output at potential. There are two reasons why the price level changes: the first is to match the decline in nominal money balances associated with lower money growth; the second is to accommodate the increased demand for real money balances associated with a lower equilibrium nominal interest rate. The second effect--which is referred to below as the "re-entry" problem--implies that the initial decline in the inflation rate exceeds its equilibrium decline. The MULTIMOD money demand function implies a total fall in the equilibrium price level in the first year of the simulation of about 14 percent: 4 percent to keep *real* money balances at their baseline level, and another 10 percent to accommodate the rise in real balances associated with a 4 percentage point decline in the nominal interest rate. Real interest rates are unchanged because both nominal interest rates and expected inflation beyond the initial period have fallen by 4 percentage points. 1/

The MULTIMOD results differ from those of the classical model because both the price level and the inflation rate are sticky. The inertia in the initial stages of a disinflationary process implies that current-period inflation does not fall by the same amount as expected future inflation. As a result, the price level initially falls by less in MULTIMOD than in the long run. In the case of Program 1, for instance, the GNP deflator drops by 3.9 percent on impact, compared to the 14 percent decline in the long run. This limits the decline in the short-term nominal interest rate to 60 basis points in the first year of the simulation, while expected inflation falls by about 5 percentage points. The resulting rise in real interest rates

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1/ The real exchange rate would also be unchanged. The open-interest parity condition implies that the real exchange rate depends on the differential between the domestic and foreign real interest rate: if real interest rates are unaffected, so is the real exchange rate.

lowers domestic spending: in addition, the induced appreciation of the real exchange rate causes a deterioration in real net exports. It takes about five years for the negative effects on aggregate demand to wear off and for output to return to baseline.

Table 4: U.S. GDP Losses for Alternative Disinflation Programs

(Percent deviation from baseline)

Program	1	2	3	4	5	6	7	8	Sum: 5 years	Sum: 10 years
1.	-2.4	-3.2	-1.9	-0.6	0.2	0.5	0.3	0.1	-7.9	-7.4
1a.	-1.4	-2.2	-1.5	-0.7	-0.2	0.1	0.2	0.1	-6.0	-5.7
2.	-1.3	-1.8	-1.2	-0.6	-0.2	-0.0	-0.0	-0.0	-5.2	-5.4
2a.	-0.8	-1.1	-0.8	-0.5	-0.4	-0.3	-0.3	-0.2	-3.5	-4.3
3.	-0.6	-1.4	-1.9	-2.0	-1.4	-0.4	0.1	0.3	-7.2	-7.0
4.	-0.4	-0.6	-0.4	-0.2	-0.2	-0.2	-0.2	-0.3	-1.9	-3.2

Description of Programs:

1. Immediate Disinflation: credible reduction in growth of the U.S. money target of 4 percent per year starting in Year 1.

1a. Pre-announced Disinflation: Program 1 starting in Year 2.

2. Phased-in Disinflation: credible reduction in growth of the U.S. money target of 1 percent per year starting in Year 1, reaching 4 percent by Year 4.

2a. Pre-announced phased-in Disinflation: Program 2, starting in Year 2 and reaching 4 percent by Year 5.

3. Noncredible Phased-in Disinflation: Program 2, with lack of credibility--observed declines in money growth are expected to continue indefinitely.

4. Very Gradual Phased-in Disinflation: credible reduction in growth of U.S. money target of 1/2 percent per year starting in Year 2, reaching 4 percent by Year 9.

The role of price stickiness in generating output losses can be reduced either by pre-announcing the policy prior to reducing the money growth rate, or by phasing-in the policy to achieve a more gradual reduction in inflation. Program 1a in Table 4 is based on a reduction in money growth that is (credibly) pre-announced in Year 1, but only implemented in Year 2. The price level initially falls in anticipation of future declines in money growth; as actual money balances remain unchanged in Year 1, the short-term interest rate drops by 160 basis points as opposed to only 60 basis points under Program 1. The appreciation of the effective exchange rate is also reduced, from 15.3 percent in Program 1 to 9.8 percent in Program 1a. Both of these factors moderate the decline in demand and output: the total output loss over the first five years is 6.0 percent as opposed to 7.9 percent. Program 2 has reductions in money growth of 1 percent in the first year of the simulation, rising linearly to 4 percent in the fourth year. The steady decline in money growth rates is assumed to be fully anticipated when the policy is introduced. The output loss in this case is 5.2 percent over the first five years, about two-thirds that observed in Program 1. Program 2a specifies the same phased reduction in money growth, but starting in the second year as opposed to the first year: this further reduces the 5-year output loss to 3.5 percent. Finally, Program 4 specifies an 8-year phase-in period for the reduction in money growth, lowering the output loss to only 1.9 percent. The sensitivity of the output loss to the disinflationary program is moderately reduced when a ten-year horizon is considered, as the gradual programs tend to postpone some of the cost to the later years.

These simulations, then, suggest that the output cost of disinflationary policies can be reduced by phasing-in or pre-announcing the policy, as long as the policy is fully credible. This may be implausible when the program is either not implemented immediately (Program 1a), or is phased-in over time (Programs 2 and 2a). To evaluate the sensitivity of the results to incomplete policy credibility, Program 3 assumes the same phased-in path of monetary deceleration as Program 2: expectations, however, adjust only to observed declines in the money growth rate as opposed to announced future declines. Specifically, the decline in expected future money growth is initially limited to the observed decline of 1 percent per year in Year 1. In Year 2, agents are surprised, as money growth falls 2 percent below baseline. By Year 4, money growth has stabilized at 4 percent below baseline and expectations have become consistent with the actual stance of policy. The initial output loss is about one fourth that in Program 1, in line with the reduction in the size of the expected money-growth shock. While the initial output cost is smaller, so is the adjustment of the price level. The sequence of surprises implied by declining money growth rates beyond the first year, then, requires further price adjustment. In the event, the cumulative output loss over the first five years is 7.2 percent, almost as large as when the cut in money growth is implemented immediately. This suggests that the potential benefits from a phasing-in of disinflationary policies can be negated if the credibility of the policy suffers as a result.

The costs of disinflation also depend on how much inertia there is in the inflationary process, which is inversely related to δ, the parameter on led inflation. As discussed in Section IV, the historical evidence is consistent with a value of slightly under 1/2. At the same time, it is interesting to examine the sensitivity of the results to different values for this parameter, both to verify the theoretical results presented in Section III, and to examine the impact of more forward- or backward-looking behavior on output costs. Simulations were performed where it varied from 1/4 to 1, the latter representing the limiting case when there is no inflation stickiness. 1/

1/ Simulations were also run with a parameter of zero on future inflation, consistent with fully backward-looking models of price behavior. These results are not shown in Table 5 because, for some of the disinflation programs, the simulations exhibited potentially explosive cyclical behavior.

The results are shown in Table 5 for Programs 1 and 2. For both programs, the cumulative output loss tends to fall as the parameter on future inflation rises. It is also apparent that the reduction in the loss is not uniform across disinflation programs: for Program 1, raising the parameter from 1/2 to 1 cuts the five-year loss in output from 7.1 percent to 5.8 percent, whereas for Program 2 the loss falls from 4.0 percent to 0.4 percent. The reason for the different reductions in the output loss for the two programs involves the path followed by the inflation rate. When the weight on future inflation is one, the inflation rate is not sticky and no output loss (or gain) is associated with "jumping" from an initial inflation rate to some arbitrary new rate, as long as it is expected to remain constant. When the decline in money growth is phased in gradually, inflation falls in the first year by 4.6 percentage points, close to the path consistent with a zero output loss when the parameter on future inflation is one. When money growth is immediately reduced by 4 percent, the inflation rate overshoots its long-run level, falling by 6.9 percentage points in the first year of the simulation, then rising gradually back to its equilibrium level of 4 percentage points below baseline. This undershooting of the inflation rate reduces the benefits associated with having a higher weight on future inflation.

Table 5: U.S. GDP Losses for Alternative Disinflation Programs With Different Degrees of Inflation Stickiness

(Percent deviation from baseline)

Program		1	2	3	4	5	6	7	8	Sum: 5 years	Sum: 10 years
1.	δ=0.25	-2.8	-4.1	-3.0	-1.4	-0.0	0.8	0.9	0.7	-11.3	-9.0
	δ=0.50	-2.2	-2.9	-1.6	-0.5	0.2	0.3	0.2	-0.1	-7.1	-7.0
	δ=0.75	-1.9	-2.2	-1.2	-0.4	-0.1	-0.0	-0.1	-0.2	-5.9	-6.6
	δ=1.00	-1.7	-2.0	-1.2	-0.6	-0.3	-0.2	-0.3	-0.3	-5.8	-7.0
2.	δ=0.25	-1.6	-2.5	-2.1	-1.5	-0.8	-0.2	0.1	0.2	-8.5	-8.2
	δ=0.50	-1.2	-1.5	-0.9	-0.4	-0.1	-0.0	-0.1	-0.1	-4.0	-4.3
	δ=0.75	-0.8	-0.8	-0.2	0.1	0.1	0.0	-0.1	-0.1	-1.7	-2.0
	δ=1.00	-0.6	-0.4	0.1	0.3	0.2	0.1	-0.1	-0.1	-0.4	-0.7

Programs: as described in Table 4.

It is of interest to compare the output losses in these disinflation scenarios with estimates of what has occurred historically. A useful short-hand measure is the "sacrifice ratio" of output loss per percentage point reduction of inflation. Estimates of the sacrifice ratio for disinflations in the United States range from 3 to 18 (Sachs (1985)); for a typical estimate (a sacrifice ratio of 6) see Gordon and King (1982). In our scenarios, the fall in inflation is always 4 percentage points, so the cumulative output losses can be divided by 4 to obtain a sacrifice ratio. It can be seen from Table 4 that our estimates do not exceed two--at the bottom end of other estimates. However, it should be emphasized that our results imply that the sacrifice ratio is not a unique number: it depends also on the phase-in, on the extent of pre-announcement, and on the credibility of the disinflation program. It could be that our estimate of output losses is low because the extent of inflation stickiness is underestimated: $\delta = 0.25$ would give a sacrifice ratio of 3 for Program 1 (Table 5). A "cold turkey" disinflation without credibility (a combination of Programs 1 and 3 in Table 4) could generate even higher sacrifice ratios. 1/

U.S. disinflationary policies also affect the economies of other industrialized countries. There are three channels at work: the impact of the reduction in U.S. economic activity on the demand for their exports of trading partners, the *increased* demand for their exports arising from the real appreciation of the U.S. dollar, and the transmission abroad of the rise in U.S. real interest rates. It turns out that the effects of these factors on the real output of the other industrialized countries are roughly offsetting, as shown in Table 6. Their output declines slightly on impact, and is roughly unchanged in subsequent years. Even for a country as closely tied to the U.S. economy as Canada, the net effect is relatively small: the principal impact being a jump in the rate of change of the absorption deflator in the first year in response to the depreciation of the Canadian dollar.

Table 6: Effects on Other Industrial Countries of an Immediate Cut in U.S. Money Growth (Program 1)

(Percent deviation from baseline)

	1	2	3	4	5	Sum: 5 years
Other Industrial Countries - Total						
Real GDP	-0.2	0.0	0.0	0.0	0.0	-0.2
Absorption Inflation	0.6	-0.2	-0.3	-0.2	0.0	
Real Effective Exchange Rate	-1.5	-0.7	-0.1	0.3	0.4	
Canada						
Real GDP	-0.2	-0.3	-0.1	0.1	0.2	-0.3
Absorption Inflation	2.0	-0.7	-0.9	-0.6	-0.1	
Real Effective Exchange Rate	-2.9	-1.7	-0.9	-0.4	-0.1	

Another question related to international spill-overs is whether the output costs of a disinflationary policy depend on the policies pursued by other countries. For instance, are the costs of disinflating in Canada independent of whether the United States disinflates or not? The answer is suggested by the results in Table 6, which indicate that Canada is little affected by disinflation in the United States. This was confirmed by

1/ Fischer (1986, Chapter 7), indicates sacrifice ratios of 1.9-3.7 (assuming perfect credibility) for a simple model with three-year contracts. He concludes that imperfect credibility is required to square the model with historical disinflation experience.

simulating disinflation programs in Canada with and without similar policies being pursued in the United States. The output loss for Canada of Program 1 amounted to 8.1 percent over the first five years of the shock in the absence of a disinflation program in the United States: the loss was raised to 8.3 percent when both countries pursued Program 1. The difference is similar to the change in Canadian output when the U.S. alone disinflates. The implication is that the output cost of disinflationary policies is not significantly affected by the disinflationary objectives of other countries. One caveat is that the credibility of the domestic policy is assumed to be unaffected by monetary policies pursued in other countries. In this context, pursuing disinflationary policies jointly with other countries would reduce the output cost if their credibility were enhanced as a result--as indicated by the results for the United States reported in Table 4.

2. Effects of more flexible labor markets: The case of Japan

The evidence in Section IV suggested that Japan may have more flexible labor markets than the other industrial countries, as reflected in larger coefficients on both capacity utilization and relative prices. Specifically, the pooled estimates give coefficients of 0.306 on the contemporaneous rate of change of the absorption price and 0.285 on the capacity utilization rate: when the Japanese coefficients are allowed to differ from those for the other regions, they are 0.675 and 0.240 respectively. After transforming capacity utilization coefficients to give estimates of β in equation (30) (by dividing by 1-a2), they equal 0.411 in the pooled case and 0.738 for Japan alone. One interpretation is that Japan has shorter contract lengths than the other countries, leading to a greater responsiveness of inflation to current economic conditions. This should reduce the output costs of a disinflationary policy by making Japan behave more like the purely classical economy discussed above: indeed, as contracts become entirely contemporaneous, the parameter on capacity utilization becomes infinite.

The results of simulations for Japan using both the original and higher parameters are shown in Table 7. When Programs 1 and 2 are simulated using the original equation, the output costs are slightly higher than those for the United States. Raising the parameters to their alternative values reduces the cumulative five-year output loss by about 30 percent for both programs 1 and 2. Greater price flexibility also leads to a sharper fall in inflation. Taking Program 1 as an example, the rate of inflation initially drops by 5.8 percentage points with the higher parameters, as opposed to 4.6 with the lower parameters.

3. Exchange-rate targeting versus monetary targeting

The disinflation programs discussed above have all been implemented through lower targets for domestic money growth. Alternatively, the authorities could use an exchange-rate target to reduce inflation. When the value of the domestic currency is fixed in terms of the currency of a trading partner with a lower inflation rate, the domestic rate of inflation will converge over time to that of the trading partner, absent an ongoing change in the real exchange rate. Under an exchange-rate target, the domestic money supply would be endogenously adjusted to prevent the exchange rate from moving out of a target band.

Table 7: Japanese GDP Losses With Different Degrees of Price Flexibility

(percent deviation from baseline)

Equations:

(1) $\Delta P = (1-0.306)\,(0.577\,\Delta P_{-1} + 0.423\,\Delta P_{+1}) + 0.306\,\Delta PA + 0.285\,(CU/100-1)$

(2) $\Delta P = (1-0.675)\,(0.570\,\Delta P_{-1} + 0.430\,\Delta P_{+1}) + 0.675\,\Delta PA + 0.240\,(CU/100-1)$

Program	1	2	3	4	5	6	7	Sum: 5 Years	Sum: 10 Years
1. - equation (1)	-2.2	-3.0	-2.1	-1.1	-0.3	0.1	0.1	-8.7	-9.2
- equation (2)	-1.7	-2.1	-1.3	-0.7	-0.3	-0.2	-0.2	-6.0	-7.0
2. - equation (1)	-1.2	-1.7	-1.3	-0.9	-0.6	-0.4	-0.3	-5.8	-7.0
- equation (2)	-0.9	-1.2	-0.9	-0.6	-0.5	-0.4	-0.3	-4.1	-5.5

Programs: As described in Table 4.

There are three potential advantages to disinflating through exchange-rate as opposed to money targeting. The first involves the credibility of the policy: the private sector may view the institutional arrangements associated with pegging the exchange rate, such as the Exchange Rate Mechanism (ERM) of the European Monetary System (EMS), as being more binding on the monetary authorities than stated objectives for domestic money growth. 1/ The second advantage relates to the re-entry problem discussed above. The lower nominal interest rates associated with lower inflation raise the demand for real money balances (provided the demand for money depends negatively on the level of interest rates): with money targeting, this requires a once-and-for-all decline in the price level in addition to that associated with the reduction in money growth. 2/ The additional downward effect on prices increases the output costs of the disinflationary policy. With a credible exchange-rate target, in contrast, the nominal money supply shifts upward to accommodate higher money demand, reducing the downward pressure on prices and the associated output cost. The third advantage of the exchange rate is that it is directly observable, unlike the money supply which is typically published only once a month and with some delay, and hence an exchange rate target conveys more information (Bruno 1990). The complicated dynamics of money demand moreover may make interpretation of money targets difficult.

1/ Giavazzi and Pagano (1988), Horn and Persson (1988).

2/ See Fischer (1986, Chapter 8), who argues for the use of an exchange rate target in stabilization programs for this reason.

There are two *disadvantages* to exchange-rate targeting. The first is the inability of the domestic monetary authorities to offset external shocks through changes in the nominal exchange rate as opposed to domestic wages and prices. 1/ This problem becomes less important the more highly integrated is the domestic economy with that of the country to whose currency the domestic currency is pegged--in particular, the greater is the extent of factor mobility and bilateral trade between them. 2/ The second disadvantage, related to the first, is that for some countries, the trading partner with which they are most highly integrated may not have a lower inflation rate. For instance, the Canadian economy is strongly linked to the U.S. economy, but both countries have similar inflation rates: pegging the Canadian dollar to the U.S. dollar would not allow Canada to disinflate, unless the United States also chose to do so.

These considerations suggest that exchange-rate targeting is more attractive when domestic inflation is initially higher than that in a major trading partner. This has been the case in the ERM: by establishing fixed parities versus the deutsche mark (or, more precisely, resisting downward realignments of those parities), non-German members such as France have successfully reduced their inflation rates to German levels. More recently, the entry of the United Kingdom into the ERM is designed to help achieve a reduction of high U.K. rates of inflation. The alternative for the United Kingdom would be to disinflate by tightening monetary conditions independently of the behavior of the exchange rate. To examine the output costs of these alternative policies, simulations were run where a 4 percent reduction in the U.K. inflation rate was achieved by exchange-rate versus money-supply targeting. 3/ The exchange-rate target was designed to be broadly consistent with a narrow-band ERM arrangement: a parity value for the pound sterling was established in terms of the deutsche mark that generated a 4 percent per year appreciation of the pound relative to its baseline path (which assumed a continual depreciation of the pound relative to the DM). Fluctuations in the exchange rate were restricted to a narrow range around this parity value. 4/

The results are shown in Table 8. For Program 1, the output loss is cut almost in half under an exchange rate target compared to a money target. The cycle in output is somewhat longer, however, with the cumulative loss over 10 years rising from 4.7 to 4.8 percent, as opposed to falling from 8.3 to 7.2 percent under a money target. The reduction in the output loss is

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1/ The conditions under which the exchange rate instrument can be abandoned without incurring much of a cost are discussed in the "optimum currency area" literature, pioneered by Mundell (1961). This issue is also considered in Fischer (1986, Chapter 8).

2/ For a survey of issues involved in currency unions, see Masson and Taylor (1991).

3/ See also Bayoumi and Chadha (1991).

4/ The details of how the ERM is incorporated in MULTIMOD are discussed in Masson, Symansky, and Meredith (1990).

consistent with the paths of the inflation rate in the initial years of the simulation: the average inflation rate in Years 1 and 2 falls by 5 percentage points (relative to baseline) with a money target, as opposed to 2.8 percentage points with an exchange rate target. As discussed above, the difference results from the price level adjustment needed to accommodate the higher demand for real money balances with a money target. The difference in output costs is even more evident when disinflation is phased in, as in Program 2. This is because the costs associated with the re-entry phenomenon for a money target are similar for Programs 1 and 2, whereas they are not relevant for an exchange-rate target.

Table 8: U.K. GDP Losses With Exchange-Rate Targeting Versus Monetary Targeting

(Percent deviation from baseline)

Program	1	2	3	4	5	6	7	8	Sum: 5 years	Sum: 10 years
1. Money target	-1.1	-2.8	-2.4	-1.5	-0.5	0.2	0.4	0.4	-8.3	-7.2
exchange rate target	-0.3	-1.0	-1.2	-1.2	-1.0	-0.6	-0.2	0.1	-4.7	-4.8
2. Money target	-0.6	-1.6	-1.4	-1.0	-0.6	-0.3	-0.0	0.0	-5.2	-5.4
exchange rate target	-0.1	-0.2	-0.4	-0.6	-0.7	-0.7	-0.5	-0.3	-1.9	-3.6

These simulations underline the importance of the re-entry problem in determining the costs of disinflation under a money target. To some extent this is an artefact of the path specified for the money supply, which makes no allowance for the one-time increase in money demand resulting from lower interest rates. If the monetary authorities could accommodate the initial rise in money demand without jeopardizing the credibility of the policy, then the output losses associated with the two targeting regimes would be closer. Indeed, if the authorities could credibly commit policy to the same path for the money supply as is implied under an exchange-rate target, the two simulations would give identical results. However, the fact that disinflation would be accompanied by periods of accelerating money growth might be very hard to justify in a context of intermediate targeting of the money supply.

VI. Conclusion

This paper has examined the transitional output costs of disinflationary policies. These costs depend critically on the form of the Phillips curve. The well-known staggered contracts models of Taylor (1979, 1980) and Calvo (1983a, 1983b) emphasize the predetermination of individual nominal wages or prices, which are revised at discrete intervals of time in an asynchronous manner. Agents are assumed to be forward looking and to set a wage in accordance with expectations of future price and output developments for the duration of the interval between revisions. The overlapping nature of the wage setting process results in an aggregate price level that is sticky. There is, however, no inherent inertia in the rate of change of the aggregate price level--the rate of inflation. Hence, these models typically imply a rapid convergence of inflation rates to their new levels with little or no output losses for relatively rapid decelerations in monetary growth. At the other extreme, if wage setters were purely backward looking (i.e., expectations were adaptive), there would be complete inflation stickiness.

A general form of the inflation equation, with inflation determined in part by the past rate of inflation and in part by expectations of future inflation, was estimated using pooled cross-section time-series data for the major industrial countries. The hypotheses that inflation was determined only by (1) expectations of future inflation as implied by the rational staggered contracts models where only the aggregate price level is sticky; or (2) by past rates of inflation, as implied by the traditional Phillips curve models with adaptive expectations, were both convincingly rejected by the data. The estimates support, therefore, an inflation equation where inflation is determined as a weighted average of past and future expected inflation.

The output costs of disinflation in a model with such a Phillips curve were examined analytically. It was shown that there is a critical value for the relative importance of the forward-looking component above which a disinflation path with zero output losses is possible. Such a disinflation path, if it exists, was shown to imply a monotonic decline in the rate of inflation. The path for the money supply, however, was shown not to be monotonic as the money stock needs to rise initially in order to accommodate increased money demand accompanying the new lower rate of inflation and avoid the re-entry problem.

The effects of alternative disinflation policies were illustrated by simulations using MULTIMOD, the Fund's multi-region macroeconometric model. The results indicate that the output costs of a disinflationary policy are smaller: (1) if the policy is announced in advance; (2) the more gradually the deceleration is phased in; (3) the more credible is the policy of disinflation; (4) (given credibility) the greater the relative importance of expected future inflation in determining current inflation; and (5) the greater the responsiveness of prices and wages to demand conditions. The international spillover effects of a unilateral disinflation in the U.S. were examined. The effects were found to be largely offsetting and, on balance, small. Finally, the effects of disinflating with an exchange rate target rather than a money supply target were examined. It was shown that such a policy could avoid the re-entry problem, since the money supply would be endogenous at the targeted exchange rate and any increase in money demand accompanying the lower inflation rate would be automatically accommodated without requiring a downward adjustment in the level of prices.

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