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WP/92/26

INTERNATIONAL MONETARY FUND

Research Department

Contacts, Credibility and Common Knowledge: Their Influence on Inflation Convergence

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March 1992

Abstract

In this paper three possible reasons are examined for a sluggish inflation response to a hard currency peg. Models of overlapping wage contracts are analyzed and shown to generate little inertia. This contrasts with the effects of government credibility and the speed of private sector learning, which are shown to have a major impact on the speed of inflation adjustment. But even if individual agents believe the government will not devalue, it is shown that inflation inertia can still arise if these expectations are not common knowledge.

JEL Classification Nos.:
E31, F31

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Summary

In recent years, EMS countries have pegged their exchange rates to the deutsche mark in an attempt to reduce their inflation to German levels. Although there have been no realignments since 1987, inflation rates have nevertheless been slow to adjust. This paper examines three possible reasons for a sluggish inflation response such as that observed in the EMS.

In the first part of the paper, the role of overlapping contracts is examined. While some inflation persistence does arise when contracts are of the Taylor type, the period of persistence following the switch to a fully credible exchange rate peg is never longer than the contract; and overlapping contracts of random length, as described by Calvo, are found to generate no inflation persistence at all.

In the second part of the paper, lack of full credibility of the peg is allowed for by assuming that the private sector expects random realignments of the exchange rate. For convenience, the model with Calvo contracts is used, which implies that all the inflation inertia must come from this lack of credibility. How fast inflation adjusts depends on how quickly people come to believe the exchange rate peg.

The third section of the paper analyzes the idea that inertia in inflation during a stabilization program might be due to a lack of "common knowledge." The usual rational expectations assumption is weakened by supposing that each agent fully believes in the peg but assumes that other agents do not and will take time to learn. The paper concludes that while inflation inertia may arise from this lack of common knowledge, it is less than indicated in Section 2 (because each agent knows the true path of the actual exchange rate).

I. Introduction

By pegging their exchange rates against the DM, EMS partner countries plan to reduce their inflation to German levels. Despite the fact that there have been no realignments since 1987, however, inflation rates have been slow to adjust. Indeed, from the evidence of European inflation indices over the period 1987-91, the authors of a recent Report on Monitoring European Integration conclude "There is no doubt therefore that inflation convergence has not occurred and it is not occurring. The differential between higher-inflation countries and Germany has recently fallen; but this has been almost entirely due to a surge in the German inflation rate which is believed to be temporary," The Making of Monetary Union, page 45.

In this paper we examine three possible reasons for a sluggish inflation response to a hard currency peg, assuming, as do the authors of the report, that "in modern industrial societies the expectations of price and wage setters are at the core of the inflation process," page 46.

Some observers have stressed the role of nonsynchronized wage bargaining in perpetuating inflation, see the for example Layard (1990), which synchronized settlements are proposed as an institutional improvement for this reason. In the first part of the paper, therefore, we look at the role of overlapping contracts. Assuming a fully credible peg and Taylor contracts, we do find some inflation persistence, but the period of persistence in inflation after the switch is never longer than the length of the contract. For overlapping contracts of random length, as described by Calvo (1983a, b), however, there is no inflation persistence from this source.

In the second part of the paper we consider what happens if the peg itself is not treated as fully credible. (A feature stressed by the authors of the report who note that realignments are still possible in the EMS.) For convenience we use the model with Calvo contracts, so all the inflation inertia must come from this pack of credibility; and we discuss how inflation adjustment depends on the process of learning about the exchange rate peg in this context.

In the third section of the paper we include as idea emphasized in Frydman and Phelps (1983) that inertia in inflation during a stabilization program may be due to a pack of "common knowledge." We weaken the usual rational expectations assumption by assuming that each agent fully believes in the peg but assumes that other agents do not and will take time to learn (in the manner analyzed in Section 2). We find that inflation inertia does arise from this lack of common knowledge, but it is less than in Section 2 (because each agent can forecast what they believe others will come to learn!)

II. Wage Contracts and Inflation Persistence

In this section we analyze the extent to which the wage contract structure induces persistence in the inflation rate. We consider both the model proposed by Taylor (1979) where wage contracts have an exogenous fixed term and the model of Calvo (1983a, b) where wage contracts are of random length.

1. Taylor contracts

A model with Taylor-type two period overlapping contracts takes the following form:

$$p_t = 1/2(x_{t-1} + x_t) \tag{1}$$

$$x_t = 1/2(p_t + \beta y_t + \hat{p}_{t+1} + \beta\hat{y}_{t+1}) \tag{2}$$

$$y_t = \eta(s - p_t + p_t^*) \tag{3}$$

where: p = log of the price level
x = log of the current new contract
y = log of output
s = log of the exchange rate (price of foreign currency)
* indicates a foreign variable

Equation (1) defines the price level as the average of outstanding contracts. The current contract, defined in equation (2), is the average of prices and demand pressure over the two periods of the contract (a hat over a variable indicates expectations conditional on time t information). Equation (3) is the IS relationship, where, for simplicity we assume that aggregate demand is not affected by the rate of interest. The exchange rate is fixed at $\bar{s}$ and, for convenience, we set $p^* = 0$.

If the pre-entry regime is one of constant monetary growth (and exchange rate depreciation) at rate μ then the (inflationary equilibrium) is as follows:

$$p_t = s_t \tag{4}$$

$$x_t = p_t + \frac{\mu}{2} \tag{5}$$

Thus, the price level tracks the exchange rate while each new contract is set above the current price level to allow for future anticipated inflation.

We assume that an announcement of an exchange rate peg is made at the start of period 0 and that the exchange rate is pegged at the level ruling in the market in period -1. For convenience we assume that $p_{-1}=0$ so $\bar{s}=0$. The value of the outstanding contract at the start of period 0 is therefore given by point A in Figure 1, where the distance OA is $\mu/2$.

With $\bar{s}=0$, the post-entry equilibrium is at the origin and the stable manifold is given by the line CC (which has a slope of $1-\sqrt{\beta\eta}$). The impact effect of the regime change is to cause a jump from point A onto CC. But by equation (1) the current price level in period 0 is related to the contract set in period 0 so, given the level of the contract set in period -1, the only feasible points in period 0 lie on the line NN in the figure (along $NN x_t = 2p_t - x_{t-1}$). Thus, the contract and price level jump to point B where CC and NN intersect. In subsequent periods, the contract and price level converge towards equilibrium at the origin by a series of steps down CC.

The implications of this solution path for inflation inertia are immediately apparent. The price level rises from period -1 to period 0 (by $\mu/(2+2\sqrt{\beta\eta})$) but in subsequent periods the price level falls towards equilibrium. Thus, the inflation rate falls in the first period after the regime switch to less than half its pre-entry value, and then turns negative in following periods!

Even though there is little persistence of inflation in this model, the regime switch does cause a long recession. Output has to be below capacity in order to drive prices down to their equilibrium level. But this recession can be avoided if the exchange rate is devalued just enough to move the post-entry equilibrium point to point U (where NN intersects the 45^{o} line). With such a devaluation equilibrium is achieved on the date of the regime change with inflation continuing at rate $\mu/2$ for one period after fixing the rate, before falling to zero.

More generally, Taylor-type contracts which are longer than two periods will cause more persistence of inflation. However, the period of positive inflation after a switch to a fixed exchange rate is never longer than the length of the contract. Thus, for instance, n period contracts will generate n-1 periods of positive inflation after a regime change.

2. Calvo contracts

In later sections of this paper, where other sources of inflation inertia are considered, it proves more convenient to use the alternative model of contracts proposed by Calvo (1983a, b). A model with Calvo contracts consists of the following equations.

$$p(t) = \delta \int_{-\infty}^{t} x(\tau) e^{-\delta(t-\tau)} d\tau \qquad or \ Dp = \delta(x-p) \tag{6}$$

$$x(t) = \delta\int_t^{\infty}[\hat{p}(\tau) + \beta\hat{y}(\tau)]e^{-\delta\tau - t}d\tau \quad or \quad Dx = \delta(x-p-\beta y) \tag{7}$$

$$y=\eta(\bar{s}-p+p^{*}) \tag{8}$$

where D = time differential operator.

In equation (6) the current price level is given as an average of all outstanding contracts, while the current new contract is a forward-looking integral of expected future prices and demand pressure as shown in equation (7). The aggregate demand relationship (equation (8)) is unchanged from the previous model.

The model can be rewritten as

$$\begin{bmatrix} Dp \\ Dx \end{bmatrix} = A \begin{bmatrix} p \\ x \end{bmatrix} + \begin{bmatrix} 0 \\ -\delta\beta 12\eta\bar{s} \end{bmatrix} \tag{9}$$

where

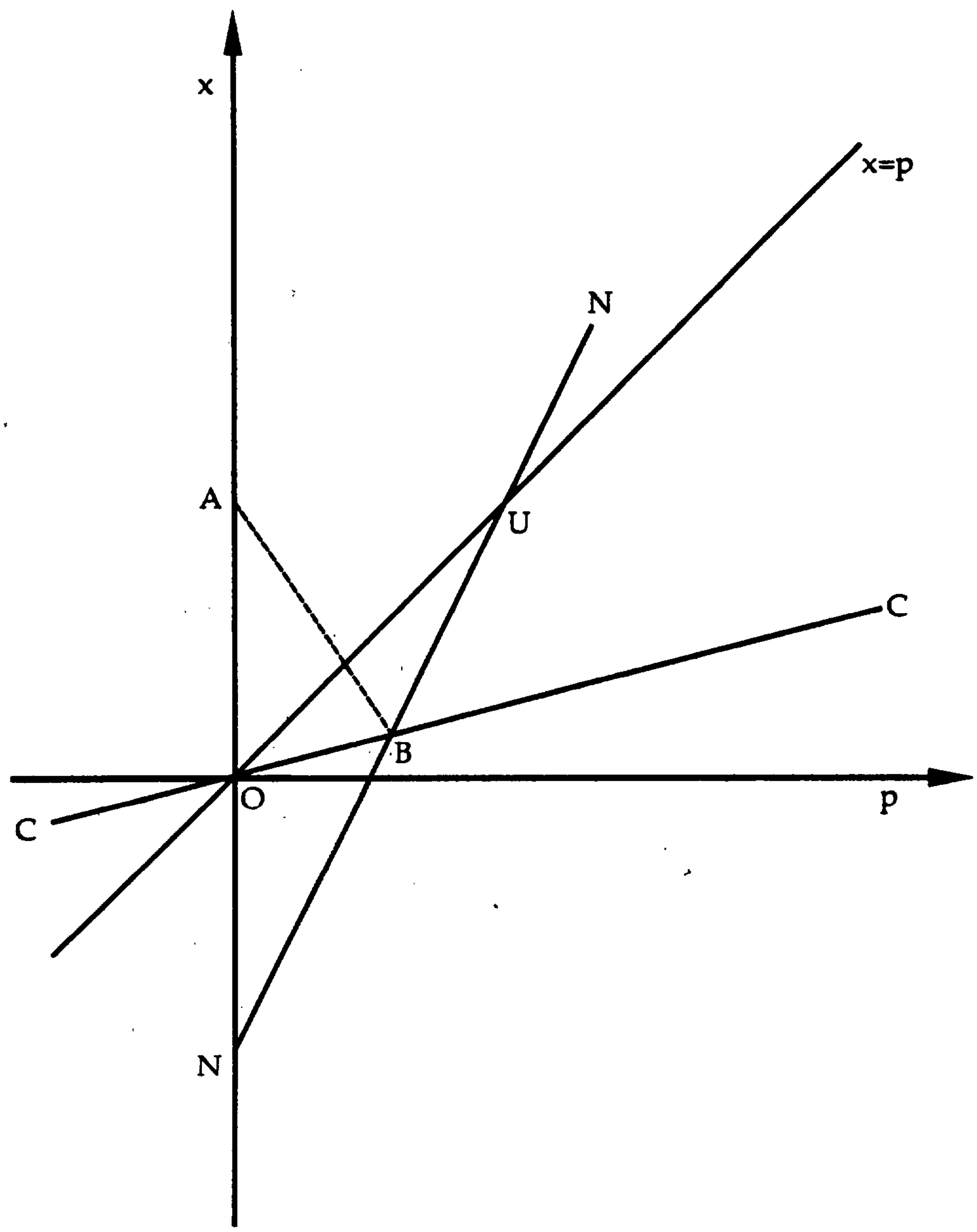
$$A = \begin{bmatrix} -\delta & \delta \\ -\delta(1-\beta\eta) & -\delta \end{bmatrix}$$

Assume that prior to joining the fixed rate system the economy was in equilibrium with constant money growth rate μ. This inflationary equilibrium implies a constant depreciation of the exchange rate μ and constant growth in the price level rate μ. It can be seen from equation (6) that the current contract must therefore be given by $x = p+\mu/\delta$. Clearly, the currently negotiated contract must be set higher than the current price level to compensate for anticipated inflation during the term of the contract. From equation (7) it can be seen that, in inflationary equilibrium, output is at its natural rate and that $p = s$ (with $p^{*} = 0$).

Again assume that the government chooses to peg the exchange rate at its market level on the joining date. Thus, if the regime switch takes place when $p = 0$ then $\bar{s}$ is set to zero and immediately prior to joining the fixed rate system the current context, x, is given by μ/δ. It is convenient to again assume that the pre-entry position is at point A in Figure 1 where the distance, OA, is now μ/δ.

When $\bar{s} = 0$, the post-entry equilibrium point is again at the origin in Figure 1, and, if the peg is <u>fully credible</u>, the post-entry solution for the contract lies on the stable manifold. It is easily shown that the slope of

Figure 1. Full Credibility



the stable manifold in this model has the same value as in the Taylor model, that is $1-\sqrt{\beta}\eta$. (In what follows this slope is denoted θ. The impact effect of the change of regime must therefore be a jump in the contract from point A onto CC. Unlike the previous model, however, this is achieved by a vertical jump from point A straight to the long-run equilibrium point at the origin. Thus, the inflation rate drops from μ to zero as soon as the peg is announced. There is, therefore, no persistence of inflation when the fixed exchange rate is fully credible and contracts are of the Calvo form.

III. Calvo Contracts and Lack of Credibility

To capture the lack of full credibility in a model with Calvo contracts, it is assumed that there is a perceived constant probability of a devaluation of size J in financial and labor markets: so the exchange rate peg suffers from a "peso problem." The perceived probability of devaluation (per unit of time) is denoted π.

In the labor market, the expectation of realignments affects the forward-looking contract (defined in integral (7)) by modifying expected future prices and demand levels. Denote the rate of change of x conditional on the current value of $\bar{s}$ by Dx. In the case where there are no expected realignments Dx is as defined in equation (7). However, when realignments are expected, the expression for Dx is

$$\begin{aligned} Dx &= \delta(x\ p-\beta y)-(1-\theta)\pi J \\ &= \delta(x-p-\beta y)-\sqrt{\beta}\eta\pi j \end{aligned} \tag{10}$$

where $\theta<1$ is the slope of the stable manifold. But when this is combined with the equation for price adjustment and the variables are measured from the current parity, we find that the system has an additional constant term. Specifically,

$$\begin{bmatrix} Dp \\ Dx \end{bmatrix} = A \begin{bmatrix} p \\ x \end{bmatrix} + \begin{bmatrix} 0 \\ b-\delta\beta\eta\bar{s} \end{bmatrix} \tag{11}$$

where A is as before and $b=(\theta-1)\pi J$. Thus, the effect of the expected realignments is to shift the "equilibrium" of the model to the north-east along the 45^{o} line. In Figure 2, the new equilibrium is marked E with associated manifold C'C', which has the same slope as CC and has a vertical intercept at $\pi J/\delta$. Because the equilibrium point E is associated with expectations of realignments which never occur, it is referred to as a "quasi-equilibrium."

$$q = \frac{(1-\theta)}{\beta\delta\eta}\pi J \tag{12}$$

measures the difference between quasi-equilibrium and true equilibrium. Hence, $q>0$ so long as $\pi J>0$.

Now consider a switch to a fixed exchange rate from a downwards float at rate μ which takes place when point A is reached. The contract jumps from point A onto the manifold C'C' at point B. At point B the rate of inflation is πJ so, in contrast to the fully credible case, inflation does not fall to zero on impact. As time proceeds, prices rise and the contract move along C'C' towards point E. The rise in prices erodes competitiveness (because the nominal exchange rate is fixed) and this causes inflation to slow. But this is at the cost of a recession which continues for as long as the expectations of realignment persist.

The assumption that the private sector permanently expects realignments at average rate πJ, despite the fact that no realignments actually occur, is obviously unsatisfactory. There is likely to be some form of learning which leads to a convergence of private sector expectations towards the true value of πJ (which is zero). Thus, as time passes the quasi-equilibrium point would also move towards the long-run equilibrium (as q is proportional to π).

In the Appendix, we indicate how a process of Bayesian updating will lead to just this sort of result where the unknown value of π (assumed by the public to be either π_H or π_L) is approximated by an estimate $\hat{\pi}$ (which exponentially converges on π_L as time proceeds without any realignments being observed. (For present purposes, $\pi_L=0$). In particular, it is shown that for large values of t (the time since the peg was fixed), the process implies that $D\hat{\pi}=-\phi\hat{\pi}$, where $\phi=\pi_H$, the high realignment probability. But since q is proportional to $\hat{\pi}$, it follows that:

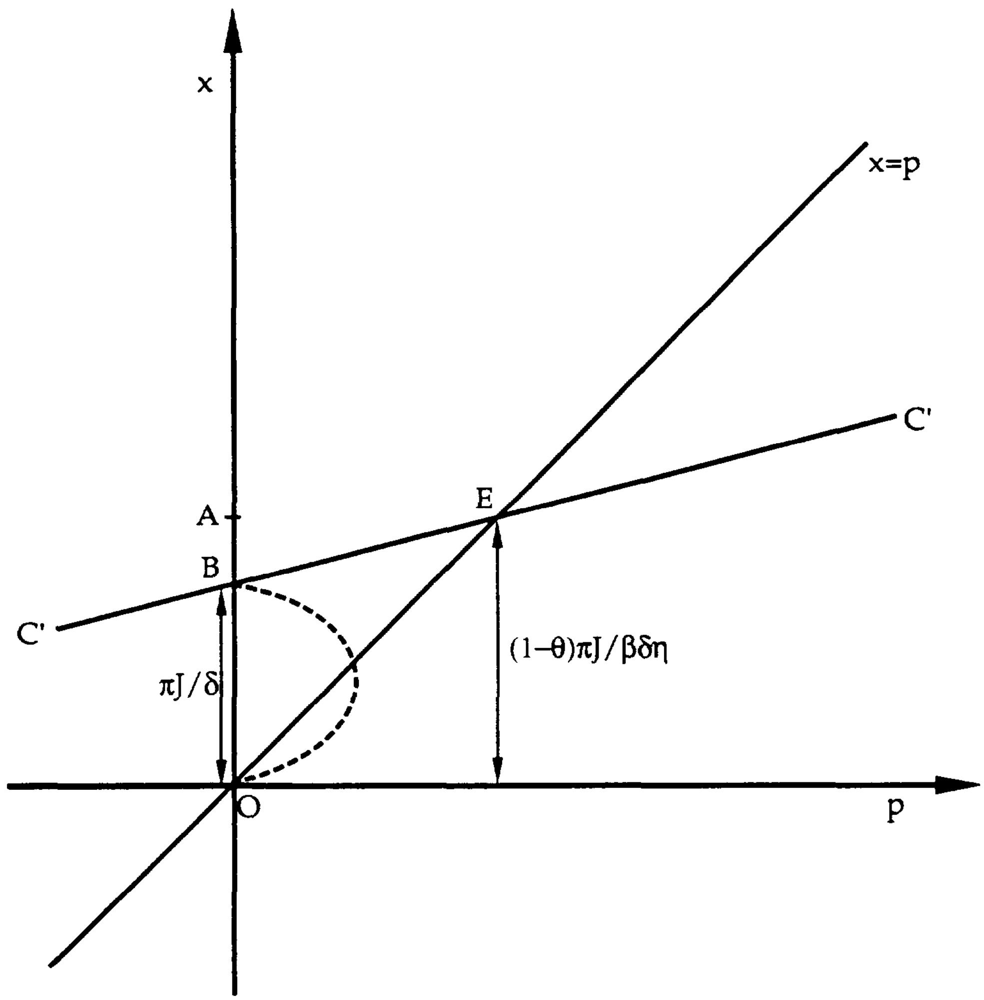
$$Dq = \phi q. \tag{13}$$

In addition, $x - q = \theta(p-q)$ on the stable manifold and $Dp=\delta(x-p)$ as in equation (6). This implies that

$$Dp = \delta(1-\theta)(q-p) \tag{14}$$

(where, for convenience, we are continuing to assume that $\bar{s}=0$). So the dynamics of adjustment under Bayesian learning may, in the neighborhood of equilibrium, be written

Figure 2. Lack of Credibility and Learning



$$\begin{bmatrix} Dp \\ Dq \end{bmatrix} = \begin{bmatrix} -\delta(1-\theta) & \delta(1-\theta) \\ 0 & -\phi \end{bmatrix} \begin{bmatrix} p \\ q \end{bmatrix} \qquad (15)$$

Where $\phi = -\pi_H$. So the adjustment of prices and contracts will follow a curved path such as that shown in Figure 2. The inflation that persists after the switch of regime causes a recession which dies away as the private sector learns that there are to be no realignments.

IV. Lack of Common Knowledge

The previous section demonstrated that, if a switch in policy regime is not fully credible at the time it is implemented and announced, then the intended effects on private sector inflationary expectations are delayed until credibility is acquired, essentially by the government "sticking to its guns." The assumption made was that agents did not believe in the government's commitment and were learning from the observations of government policy and that each individual agent regarded his or her own beliefs as being held by all other agents.

In this section, however, we examine not the lack of credibility but rather the "lack of common knowledge," along the lines suggested by Frydman and Phelps (1983, Chapter 1). They emphasize that, even where agents know the true parameters of the model and the intended change of policy is announced,

> The agent's forecasting problem is further complicated when government policy alters the parameters of the process governing the behaviour of exogenous variables [...by] the problem that although an individual agent may know and believe the government's announcement he does not know if other agents also know and believe in the change in policy. ...Where the rational expectations approach predicts instantaneous movement to a new equilibrium, the difficulties faced by agents in their expectations formation lead to a protracted period of disequilibrium (page 6, emphasis added).

In the Calvo model it was indeed found that rational expectations and policy credibility ensured instantaneous adjustment to a new non-inflationary equilibrium despite the presence of overlapping contracts. To capture the issues discussed in Frydman and Phelps (1983), we continue to assume that the model parameters are known to all agents and also that the policy shift is announced and is believed by every agent. But, because agents do not know about the beliefs of others, they are assumed to incorporate a model of learning in their forecasts of wage settlements--and the model they use for this purpose is that suggested in equation (9) of Section 2!

This does of course imply that, during the period of transition from one policy rule to another, agents misperceive the expectations of other agents: after all everyone knows what the policy is, so what is going on is not learning about policy but eliminating errors in forecasting the behavior of others. This view of the world is rather asymmetric (everyone is inwardly sure but is not sure about others) but may be appropriate in circumstances where the credible policy commitment made by the government involves a considerable change of regime whose consequences for collective behavior have not been fully spelled out. That this may be true of monetary disinflations was argued by Phelps and Di Tata in Frydman and Phelps (1983, Chapter 2 and Chapter 3); and it may also be applied to a change of exchange rate regime.

To see what happens under our somewhat stylized account of the lack of common knowledge, we proceed at first to see how forecasting the learning of others affects current contracts. The result obtained is that the time path of the price level mimics what would have been true with genuine learning; but because agents do here anticipate what cannot be forecast if everyone was really learning, the price level is always closer to equilibrium.

As in Section 1 we continue to assume that prices are an (infinite) moving average of past contracts, see equation (6), and that contracts are weighted forecasts of future prices and output levels, see equation (7). But we reject the rational expectations assumption that the forecasts will be generated by the model itself (including the credibly fixed exchange rate peg), and assume instead that the forecast for prices is given by the learning model in equation (15).

The expected values of p and y, denoted $\hat{p}$ and $\hat{y} = -\eta\hat{p}$, now involve forecasting the forecasts of others. From equations (13) and (14) the following autonomous system is obtained describing the evolution of the expected price level and quasi-equilibrium.

$$D\hat{p} = \delta(1-\theta)(\hat{q}-\hat{p}) \tag{16}$$

$$D\hat{q} = -\theta\hat{q} \tag{17}$$

For convenience we combine this with the equations that describe actual prices in the following matrix system.

$$\begin{bmatrix} D\hat{q} \\ D\hat{p} \\ Dp \\ Dx \end{bmatrix} \begin{bmatrix} -\phi & 0 & 0 & 0 \\ (1-\theta)\delta & -(1-\theta)\delta & 0 & 0 \\ 0 & 0 & -\delta & \delta \\ 0 & -\delta(1-\beta\eta) & 0 & \delta \end{bmatrix} \begin{bmatrix} \hat{q} \\ \hat{p} \\ p \\ x \end{bmatrix} \tag{18}$$

The roots of this system are conveniently displayed on the diagonal; there are three stable roots and one unstable root (δ). We assume that the contract will jump as necessary to remain on the stable manifold to ensure stability. This allows us to write:

$$x = v_1\hat{q} + v_2\hat{p} + v_3 p \tag{19}$$

where

$$[v_1 \quad v_2 \quad v_3 \quad -1][\delta I - A] = [0 \quad 0 \quad 0 \quad 0] \tag{20}$$

$[v_1 \quad v_2 \quad v_3 \quad -1]$ being the LHS row eigenvector associated with the unstable root and A is the matrix appearing in (4) (see Dixit (1980)).

In this case, we find specifically that the parameters entering the determination of the current contract are:

$$v_1 = \frac{1-\beta\eta}{2-\theta}$$

$$v_2 = \theta$$

$$v_3 = 0$$

where $\theta = 1-\sqrt{\beta\eta}$, as in Section 1. With contracts determined in this way, equation (5) can be reduced to a third order system, namely

$$\begin{bmatrix} D\hat{q} \\ D\hat{p} \\ Dp \end{bmatrix} \begin{bmatrix} -\phi & 0 & 0 \\ (1-\theta)\delta & -(1-\theta)\delta & 0 \\ -\dfrac{(1-\beta\eta)\delta}{2-\theta} & -\theta\delta & -\delta \end{bmatrix} \begin{bmatrix} \hat{q} \\ \hat{p} \\ p \end{bmatrix} \tag{21}$$

The term θ could have either sign: but in simulating these equations, we assumed it to be positive. Specifically, we assume $\beta=\eta=1/2$ so $\theta=1/2$, setting $\delta=\phi=1/2$ too generates the results shown in Figure 3. It is assumed that both the price level and the forecast begin at equilibrium, but $\hat{q}$ is positive, specifically $\hat{q}(0) = 1$. Consequently, both p and $\hat{p}$ rise for three periods before falling back towards equilibrium. (Note that in this case p and $\hat{p}$ are perfectly correlated, specifically $p=0.25\hat{p}$.)

Note that the initial conditions are those in which a rational expectations solution of this model would have led to instant price stabilization; no realignments are expected by any individual and the price is at equilibrium. But we assume here that each agent thinks that others expect devaluation ($q>0$) and that they will only gradually learn that they are mistaken. So each person forecasts high settlements and this leads to the price level rising, and to unemployment. The forecast inflation falls because of "learning" ("those silly people may be wrong but they will learn") and because of unemployment. Note that y is proportional to p, ($y=-\eta p=-0.5p$).

If the speed of learning postulated for others is much slower, then the phase of rising prices will be that much more prolonged, and so too the period of slack demand. For the second simulation shown in Figure 4, ϕ has been much reduced ($\phi=0.1$) and this means that inflation lasts twice as long, with prices peaking in period 6. In this case, the actual price level moves more closely in line with the forecast price level as $p=0.417\hat{p}$.

The example we have worked through is one in which agents can correctly forecast government policy, but do not correctly forecast the forecast of others. For an open economy with a pegged exchange rate it illustrates the point made by Phelps that "in order to reduce the price level (in relation to the accustomed trend), it is not sufficient that the central bank persuades each agent to reduce his private expectations of the money supply (in relation to past trend) by the warranted amount. The prevelance of this knowledge must be public knowledge--an accepted fact." (For the open economy one needs to replace the money supply by the exchange rate in the quotation.)

Like other examples of this genre, it is subject to the criticism that people could work out that they are wrong about the forecasts of others; and also that the central bank would surely in the circumstances do its best to publicize the private credibility that its policies enjoy (by conducting a poll for example). But the learning process may take some time--long enough to be judged a failure. And the task of persuading the general public that the policy is widely believed may well in practice include "convincing them that groups that they regard as powerful have already bought it. Appealing over the heads of these groups to the people will not work unless you can simultaneously persuade them that traditionally powerful groups are no longer so strong as to be able to deflect you from your policy" (Bull (1983), comment on Di Tata in Frydman and Phelps).

Our example is not meant to demonstrate the impossibility of securing convergent beliefs; rather to illustrate how policymakers need to work actively to secure this end rather than simply leaving it to "rational expectations."

Figure 3: phi=0.5

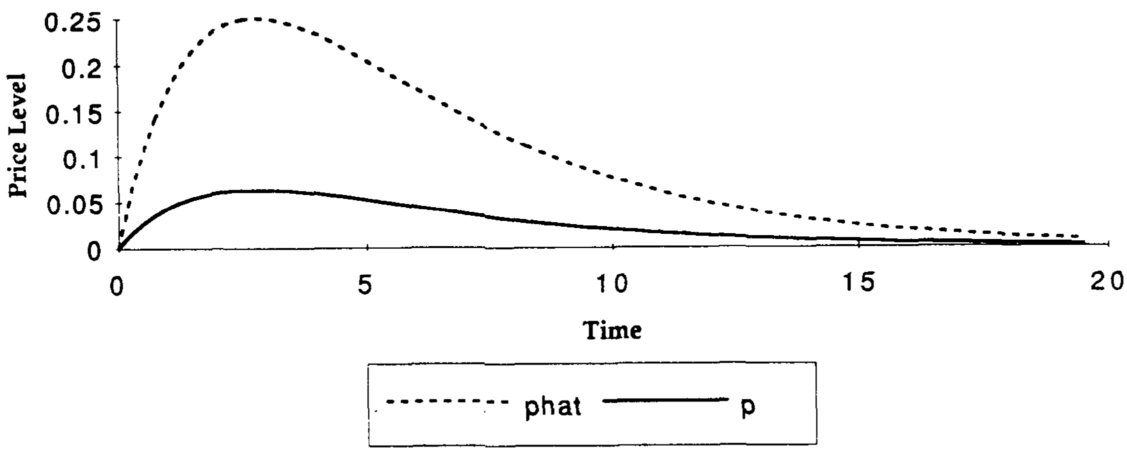
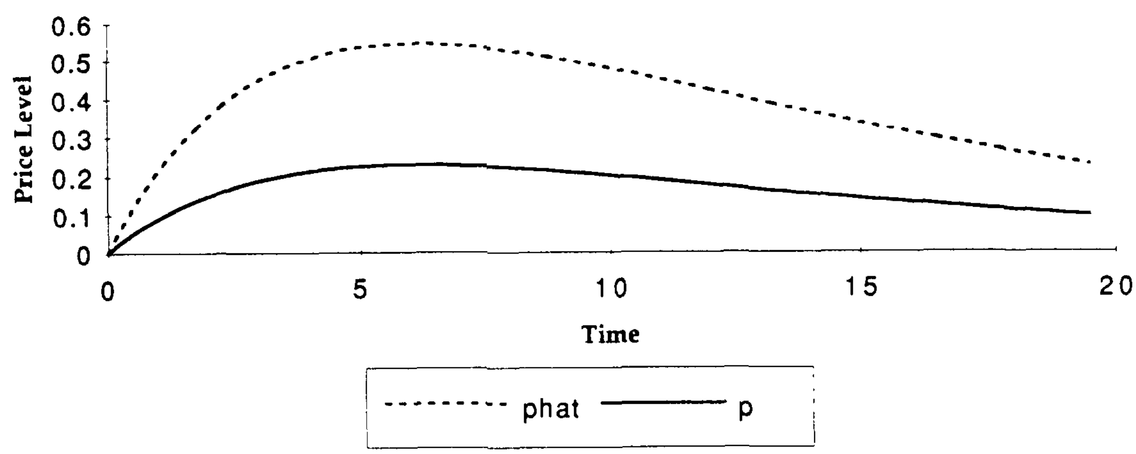


Figure 4: phi=0.1



V. Conclusion

In this paper we consider various possible explanations for a protracted process of inflation convergence after a switch to a hard currency peg. Assuming a fully credible peg and rational expectations, it appears that nominal stickiness in the form of Taylor contracts does not account for much inflation sluggishness cf. Giovannini (1990) who concludes that "This is not to say that nominal inertia is irrelevant, but only that additional explanations may be useful." To focus clearly on these additional explanations we proceed by working with Calvo contracts, for which nominal inertia implies no sluggishness for inflation whatsoever.

By making agents anticipate random realignments, we allow for the hard peg to be less than fully credible. This devaluation prospect does of course impart an inflationary bias to the economy--but this inflation gets converted into economic slack if no realignments actually take place. It seems implausible that agents would permanently expect realignments in these circumstances, so we allow for Bayesian learning about the policy shift.

This combination of nominal inertia and credibility which is slow to build generates sluggish inflation and a protracted recession after a peg is adopted. The roots of the process depend essentially on the expected life of contracts and on the speed of learning.

Lastly we follow the lead of Frydman and Phelps by relaxing the common knowledge assumption implicit in the usual rational expectations hypothesis. The way this is done is for each agent to postulate that others are learning about the policy switch while he or she knows it to have happened for sure. Since no one is in fact learning, the speed of adjustment is faster than in the case where genuine learning takes place. But if the intensity of realignments is not expected to be very high (i.e., π_H is not high) then this process can be protracted.

If indeed the problem is one of learning, either about the policy shift or about the views of others, then there is presumably a good case for the authorities trying to signal the change of policy in a way which will speed up the learning process. But we do not discuss this here.

Bayesian Learning about the Realignment Probability

The realignment expectations discussed in the text can be derived from a model of Bayesian learning, as shown in Driffill and Miller (1991). The argument may be summarized briefly as follows.

After the exchange rate is pegged, the public still believes that realignments of size J may occur as a Poisson process--but they are not sure of the intensity, π. Assume specifically that their uncertainty is simply whether this intensity is high (π_H) or low (π_L) and suppose they start out immediately after the end of floating with initial probability $P_H(0)$ and $P_L(0)=1-P_H(0)$ attached to each of these intensities, i.e., $\pi(0)=P_H(0)(\pi_H-\pi_L)+\pi_L$. If these probabilities are then updated in a Bayesian fashion, then as long as no realignments take place, P_H declines exponentially towards zero. Specifically

$$P_H(t) = \frac{1}{1+\exp\{(\pi_H-\pi_L)t\}(1-P_H(0))/P_H(0)} \qquad (A1)$$

where time t is measured from the date at which the rate was first pegged.

If a realignment occurs at time t, then this causes a discrete jump in $P_H(t)$ so

$$P_H(t^+)-P_H(t^-) = \frac{(1-P_H(t^-))\,\frac{\pi_L}{\pi_H}}{1+\frac{(1-P_H(t^-))}{P_H(t^-)}\,\frac{\pi_L}{\pi_H}}$$

Thereafter P_H will decline exponentially from its new high value just as in equation (A1), but measuring time from the date of the realignment.

Note that for large values of t,

$$P_H(t) \approx e^{-(\pi_H 0 \pi_L)}\left[\frac{P_H(0)}{1-P_H(0)}\right]$$

and so, if $\pi_L = 0$, then for large t

$$\hat{\pi}(t) = P_H(t)\pi_H \approx e^{-\pi_H t}\hat{\pi}(0)$$

so

$$D\hat{\pi} = -\pi_H\hat{\pi}$$

the result we use in the text.

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