Discretionary Monetary Policy and Inflation Persistence[☆]

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Abstract

Rational expectations models of staggered price/wage contracts have failed to replicate the observed persistence in inflation and unemployment during disinflation periods. The current literature on this *persistency puzzle* has focused on augmenting the nominal contract model with imperfect credibility and learning. In this paper, I re-examine the persistency puzzle by focusing on the discretionary nature of monetary policy. I show that when the central bank is allowed to re-optimize a quadratic loss function each period, imperfect credibility and learning, even in the absence of staggered contracts, can generate a significant amount of inflation persistence and employment losses during a disinflationary period.

Keywords: Monetary policy; Disinflation; Credibility; Inflation persistence

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1. Introduction

The New Keynesian sticky price/wage framework has been criticized for its empirical failure to generate sufficient inflation and output persistence.[1] This so-called persistency puzzle has led researchers to more closely examine the theoretical problems of generating observed output and inflation dynamics. In particular, a group of models has emerged attempting to improve the empirical fit of the New Keynesian framework by augmenting it with imperfect credibility and learning.[2] This literature asserts that the persistency puzzle arises because of the empirically questionable assumption of perfect policy transparency, and not because of any intrinsic shortcomings of the contract structure. The idea is that if policy suffers from imperfect transparency and credibility, then the public is forced to learn the true intentions of the monetary authorities by observing real outcomes. It is this learning process that is likely to generate additional persistence in inflation and output dynamics. For example, Erceg and Levin (2001) use a contract model similar to Taylor (1983) and argue that by including imperfect information and learning they can account fairly well for the dynamics of inflation and output following the Volker-disinflaition in 1979.

The problem with these learning models is that they typically assume that the monetary authorities do not behave optimally, but instead simply follow an exogenously

[1] Phelps (1979) and Taylor (1983) show that forward-looking staggered wage contracts do not necessarily lead to an initial decline in economic activity following a disinflationary shift in monetary policy. Ball (1994) demonstrates that contractionary monetary policy coupled with staggered price setting can even give rise to a boom in output. Fuhrer and Moore (1995) also show that the New Keynesian Phillips curve derived from overlapping wage contract fails to account for the observed persistence in inflation.

[2] For example, Erceg and Levin (2001), Andolfatto and Gomme (1999), and Hugh and Lansing (2000).

determined Taylor rule. As a consequence, the explicit relationship between discretionary monetary policy and inflation and output dynamics is disregarded.[3]

The main reason for sidestepping the central bank's optimization problem is the difficulties of modeling optimal policy in an environment of imperfect information and learning. However, this is not without consequences. For instance, the common specification of the Taylor rule includes lags of the central bank's control instrument. This exogenously assumed policy inertia is not only likely to create inflation persistence in itself but also makes it harder for agents in the economy to learn the true nature of the current regime and thus reinforce the persistence in both output and inflation. The question then is how much of the persistency is really generated endogenously through imperfect credibility and transparency and how much is exogenously assumed by eliminating discretionary monetary policy in favor of an appropriately specified Taylor rule.[4]

In this paper, I re-examine the persistency puzzle by focusing on the discretionary nature of monetary policy. In particular, I study how credibility and transparency affect inflation and unemployment dynamics through discretionary policy as opposed to nominal rigidities. Using a modified version of Barro and Gordon's (1983) neoclassical model of discretionary policy, I show that when the central bank is allowed to re-

[3] In the conclusion of their paper, Erceg and Levin (2001) do recognizes this limitation of their model and suggest that future research should give explicit considerations to the relationship between discretionary policy and imperfect credibility and transparency.

[4] Another interesting feature of these learning models is that the importance of credibility and transparency as determinants of disinflation costs depend on the nature of the staggered contract. For example, Erceg and Levin (2001), use a contract specification similar to Taylor (1983) and find that credibility does have a fairly large effect on disinflation costs. Hugh and Lansing (2000), on the other hand, make use of Furhrer and Moore's (1995) model of staggered wage contracts, which by construction gives rise to inflation persistence. Not surprisingly, they find that credibility does not have a major impact on the cost of disinflation. Thus, Learning models without structural inflation persistence suggest that improved transparency and credibility reduce costs associated with contractionary monetary policy, while models built around structural inflation persistence suggest that these actions are relatively fruitless.

optimize a quadratic loss function each period, imperfect credibility and transparency, even in the absence of staggered price/wage contracts, can generate a significant amount of inflation persistence and employment losses during a disinflatonary period. Hence, I identify an additional channel, unrelated to nominal rigidities, through which credibility and transparency affect inflation and unemployment dynamics. [5]

The relationship between optimal policy and inflation dynamics has been discussed extensively in the past. In their seminal paper, Kydland and Prescott (1977) demonstrate that discretionary policy can be dynamically inconsistent and therefore produce excess inflation. Barro and Gordon (1983b) extend the framework and show that dynamically inconsistent monetary policy predicts a positive relationship between inflation and the natural rate of unemployment. Thus, any persistence in inflation should be directly related to persistence in the natural rate. Ireland (1999) set out to test this hypothesis using quarterly U.S data. Indeed, he finds a strong positive long-run relationship between inflation and unemployment. However, his results also indicate that the Barro-Gordon model (henceforth BG model) fails to explain the short-run relationship between the two time series. In this paper I suggest that the latter result most likely arises for two reasons. Firstly, the preferences of the monetary authorities changed over the sample period. For example, most observers would agree that the Volker-disinflation reflected a change in the Federal Reserve's objective function. Secondly, even if regime shifts were taken into account, the BG model predicts that a disinflation induced by a change in the preferences of the monetary authorities is immediate and completely costless in terms of employment losses. This, of course, is due to the

[5] The notion that inflation persistence may not simply be an inherent feature of staggered price/wage contracts but may generated through imperfect credibility alone was first put forth by Sargent (1986).

assumption that the private sector has perfect information regarding the preferences of the monetary authorities. Taking these two concerns into account, this paper analyzes a disinflationary regime shift in an environment where monetary policy is discretionary, but where the public has imperfect information regarding the true preferences of the monetary authorities. I show that in this setting the BG model does predict persistence in unemployment and inflation following a regime shift, and that the degree of this endogenous persistence is strongly influenced by the level of credibility and transparency.

The intuition for this result is straightforward. Assume that the central bank announces that it is going to be tough on inflation. If the central bank lacks credibility, the announcement will have little effect on inflation expectations. Since the monetary authorities do not believe that they can credibly manipulate inflation expectations, they perceive a quick disinflation to be highly costly. Consequently, in order to limit short-run employment losses the monetary authorities find it optimal to reduce inflation gradually.[6] The problem is that since policy is not perfectly transparent the public assesses the likelihood of a regime shift from observing real outcomes. Hence, a small reduction in inflation provides little information in this regard and is likely to only affect inflation expectations marginally. This, of course, forces the monetary authorities to continue its gradual disinflation. Thus, the failure of discretionary policy to incorporate the impact of credibility and transparency on the dynamics of inflation expectations leads to a dynamically inconsistent disinflation characterized by excessive employment losses and persistent inflation.

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[6] The initial decline in inflation depends on how "large" the regime shift is. The higher losses in employment the central bank is willing to sacrifice for a perceived reduction in inflation, the less gradual the disinflation is likely to be.

The paper is structured as follows. Section 2 presents the original BG model. Section 3 introduces incomplete information and learning and analyzes, through simulations, the nature of the relationship between inflation and unemployment persistence and credibility and transparency. Section 4 reviews the work of Ireland in light of the Volcker disinflation, and shows how the model presented in section 3 can potentially explain the empirical failure of the simple BG model. Section 5 concludes.

2. The Barro-Gordon Model

2.1 The Economy

In the BG model, the unemployment rate is the measure of real activity and postulated by the neoclassical expectation-augmented Phillips curve:

$$U_t = U_t^n - b\left(\pi_t - E\left[\pi_t \middle| \Omega_{t-1}^P\right]\right) \tag{1}$$

Equation (1) says that the unemployment rate is determined by the natural rate of unemployment, U_t^n, and the magnitude of the surprise inflation, $\pi_t - E\left[\pi_t \middle| \Omega_{t-1}^P\right]$. Private agents base their inflation expectations on information gathered during time t-1, denoted by Ω_{t-1}^P. The superscript emphasizes the fact that the public's information may be constrained i.e., $\Omega_{t-1}^P \subset \Omega_{t-1}$. Thus, as opposed to the New Keynesian Phillips curve, anticipated changes in inflation have no effect on current economic activity only unanticipated changes do. The natural rate is assumed to vary over time according to an AR(1) process:

$$U_t^n = \lambda U_{t-1}^n + (1-\lambda)\overline{U}^n + \varepsilon_t \qquad (2)$$

where ε_t is serially uncorrelated and normally distributed with mean zero and variance σ_ε^2. If $|\lambda| < 1$, the natural rate is stationary with a long-run level of $\overline{U}^n$. Hence, the key to understanding the dynamics of the unemployment gap is to know how private agents form their expectations. If agents are assumed to have complete information and to form their expectations rationally, then they will never commit systematic forecast errors and thus unemployment would never be persistently above or below its natural rate. In section 3, restrictions will be imposed on the information set Ω_{t-1}^P such that private agents can, at least in the short-run, rationally commit systematic forecast errors. For future reference, because of potential differences in information sets, expectations of private agents are denoted by E^p, while expectations of the monetary authorities are denoted by E^{CB}.[7]

2.2 Discretionary Monetary Policy

The objective of the monetary authorities is to minimize the variance of unemployment and inflation around respective targets. That is, they will minimize the following loss function:

$$L = E_t^{CB}\, \tfrac{1}{2}\left\{(U_i - U_i^*)^2 + \omega(\pi_i - \pi^*)^2\right\} \qquad (3)$$

[7] I will assume that $\Omega_t^{CB} = \Omega_t$, i.e., the central bank has access to the full information set.

U_t^* is the socially optimal level of unemployment and π^* is the inflation target.[8] The coefficient ω reflects the relative weight that the authorities put on inflation variability versus unemployment variability. In this simple set-up, it is further assumed that the central bank controls the actual inflation level. However, they cannot perfectly set the inflation level due to some control error. Therefore, the realized inflation consists of the monetary authorities' optimal inflation level determined at the beginning of period *t*, π_t^{OP}, and an error term η_t:

$$\pi_t = \pi_t^{OP} + \eta_t \tag{4}$$

where η_t is serially uncorrelated and normally distributed with mean zero and variance σ_η^2. Thus, the central bank will minimize the loss function (3) with respect to π_t^{OP} and subject to the expectation-augmented Phillips curve (1) and equation (2).

There are two crucial assumptions in this model. First, discretionary policy is restricted to mean that current and future inflation expectations are taken as given by the central bank when minimizing the loss function. This reflects the monetary authorities' conviction that they cannot credibly manipulate expectations in the absence of commitment.[9] Second, the unemployment target U^* is below the natural level of unemployment, and will be set at $U^* = kU_t^n$ where $0 < k < 1$. The target, U^*, can be

[8] The loss function could be specified as an infinite period function discounting future losses. However, the model assumes that the central bank takes inflation expectations as given when setting the optimal inflation rate, and hence the infinite-period function collapses to one period optimization problem.
[9] See Clarida, Gali and Gertler (1999) for a discussion with respect to this interpretation of discretionary policy.

viewed as the efficient level of unemployment in the presence of market imperfections such as unemployment compensation, income taxation or imperfect competition.

By minimizing the loss function we can derive the reaction function of the central bank:

$$\pi_t^{OP} = \pi^* + \frac{b}{\omega + b^2}(1-k)E_{t-1}^{CB}U_t^n + \frac{b^2}{\omega + b^2}(E_{t-1}^P[\pi_t] - \pi^*) \qquad (5)$$

From equation (5), it is clear that if the monetary authorities only care about stabilizing the unemployment level i.e., $\omega = 0$, then the optimal response to an increase in inflation expectations is to raise inflation by an equal amount. However if $\omega > 0$, the monetary authorities will move inflation in a less than one to one fashion with inflation expectation and instead permit unemployment to digress from its efficient level. The larger ω is, the less the central bank cares about inflation expectations and the more prepared it is to accept employment losses in order to keep inflation close to its target.

2.3 Equilibrium Inflation and Unemployment

By assuming that the public has complete information and that they form their expectations rationally i.e., $\Omega_{t-1}^P = \Omega_{t-1}$ and $E_t^P[\pi_t] = \pi_t^{OP}$ we can find the following expressions for equilibrium inflation and unemployment.

$$\pi_t^{OP} = \pi * + \frac{b}{\omega}(1-k)E_{t-1}^{CB}\left[U_t^n\right] \quad (6)$$

$$U_t = U_t^n - b\eta_t \quad (7)$$

Equation (6) shows that equilibrium inflation is higher than the target. This famous results arises because the monetary authorities are, in each period, faced with the temptation to create surprise inflation in order to push unemployment below it natural level and closer to its socially optimal level.[10] However, rational agents will anticipate such behavior and incorporate it into their expectations. Thus, in equilibrium there is excess inflation and no gain in terms of lowered unemployment. This implies, as is clear from equation (7), that the unemployment gap only depends on the control error. Consequently, monetary policy does not have a real effect on the economy. Furthermore, since the cost associated with excess unemployment (i.e., the difference between the actual and the socially optimal level) is convex, the perceived benefits from inflating are greater at higher levels of unemployment. The theory therefore predicts that the inflation-bias is positively correlated with the natural rate of unemployment. Equations (6) and (7) also clearly show that a disinflation triggered by a change in the preferences of the monetary authorities is immediate and completely costless

[10] The temptation to create surprise inflation does not necessarily have to reside within the central bank, but can arise because of political pressure.

3. Introducing Incomplete Information and Learning

3.1 Asymmetric Information and Bayesian Updating

The crucial assumption in the proceeding analysis is that the public can not observe ω i.e., the relative weight assigned by central bank to inflation variability in the loss function. Let us assume that a regime shift has taken place and that ω_O and ω_N be the preference parameters belonging to the old and new regime respectively. Since the public cannot observe the true value of ω, they are not sure whether a regime shift has taken place or not. Initially, possibly as a response to an announcement by the monetary authorities, the public assigns a prior probability, P_0^N, to the event that the regime shift has occurred. If P_0^N is close to one, the announcement by the central bank is viewed as credible while a value close to zero would indicate low credibility. As time passes the public will update the probability of being in the new regime. Under these assumptions inflation expectations for period *t* can be expressed as:[11]

$$E_{t-1}^{P}[\pi_t] = P_{t-1}^{N} E_{t-1}^{P}[\pi_t | \omega = \omega_N] + (1 - P_{t-1}^{N}) E_{t-1}^{P}[\pi_t | \omega = \omega_O] \tag{8}$$

If the public believe that there was no regime shift, they would expects π_t to be drawn from a normal distribution with variance σ_η^2 and mean $E_{t-1}^{P}[\pi_t | \omega = \omega_O]$. On the other hand, if they believe that the regime shift did in fact take place, they would expect π_t to be drawn from a normal distribution with the same variance but with a mean of

[11] I assume that the public does not assign transition probabilities i.e., they do not think that once there has been a regime shift there is any risk that the monetary authorities will switch back.

$E_{t-1}^{P}\left[\pi_t \middle| \omega = \omega_N\right]$.[12] Once the public has observed the realized inflation they will use Bayes rule to update P_t^N. That is,

$$P_t^N = \frac{P_{t-1}^N f_t\left(\pi \middle| \omega = \omega_N\right)}{P_{t-1}^N f_t\left(\pi \middle| \omega = \omega_N\right) + \left(1 - P_{t-1}^N\right) f_t\left(\pi \middle| \omega = \omega_O\right)} \tag{9}$$

where, $f_t\left(\pi \middle| \omega = \omega_N\right)$ is the probability of observing π at time t conditional on $\omega = \omega_N$, and $f_t\left(\pi \middle| \omega = \omega_O\right)$ is the probability of observing π_t time t conditional on $\omega = \omega_O$.

Since the agents are rational and the regime shift has indeed taken place, the realized inflation will be drawn from the normal distribution with a mean equal to $E_{t-1}^{P}\left[\pi_t \middle| \omega = \omega_N\right]$.

3.2 Inflation and Unemployment Dynamics

The equilibrium inflation and unemployment at time t can be derived as (see appendix):

$$\pi_t^{OP} = \pi^* + \frac{b}{\omega_N}(1-k)\theta_{t-1}E_{t-1}^{CB}U_t^n \tag{10}$$

$$U_t = U_t^n + (\theta_{t-1} - 1)(1-k)E_{t-1}^{CB}U_t^n - b\eta_t \tag{11}$$

where

$$\theta_t = \frac{\omega_N\left(b^2 + \omega_O\right)}{\omega_O\left(b^2 + \omega_N\right) + P_t^N b^2\left(\omega_N - \omega_O\right)} \tag{12}$$

[12] If the monetary authorities react to anticipated future shocks, the variance of the two conditional distributions will differ. This is because the response by the central bank today to perceived future shocks depends on the preferences i.e., ω. If a negative supply shock is expected, then the larger ω is, the less the optimal inflation level will increase.

I define a time-varying parameter θ_t in order to simplify the expressions and will refer to it as the learning parameter. It is clear from (12) that $\theta_t \to 1$ as $P_t^N \to 1$. Furthermore, if there has been a disinflationary regime shift i.e., $\omega_N > \omega_O$, then $\theta_t \geq 1$. On the other hand, if there has been an inflationary regime shift i.e., $\omega_O > \omega_N$, then $\theta_t \leq 1$. [13]

Equation (10) indicates that inflation will decrease after a disinflationary regime shift and increase after an inflationary regime shift. However, because of the learning process and the implied optimal policy, a disinflation is no longer immediate but gradual. Equation (11) shows that following a disinflationary regime shift, the unemployment rate will systematically be above the natural rate as long as the public is unsure about which regime they are in. The unemployment gap will approach zero as the learning parameter θ_t converges to one.

The intuition for these dynamics is fairly simple. If the announcement to disinflate lack credibility, then inflation expectations will not be significantly affected. Facing high inflation expectations, the monetary authorities perceive a quick disinflation to be extremely costly and consequently find it optimal to gradually reduce inflation. The problem is that the public assesses the likelihood of a regime shift from observing realized inflation. Hence, a small reduction, given imperfect transparency, provides little new information and inflation expectations will therefore only adjust marginally. This of course, forces the monetary authorities to continue to reduce inflation gradually. Thus, the failure of optimal policy to incorporate the impact of credibility and transparency on the dynamics of inflation expectations leads to a dynamically inconsistent disinflation. It

[13] Also if $\omega_N > \omega_O$ then $b(1-k)/\omega_O > \left(b(1-k)/\omega_N\right)\theta_t \ \forall t$ and if $\omega_O > \omega_N$ then $b(1-k)/\omega_O < \left(b(1-k)/\omega_N\right)\theta_t \ \forall t$.

is in this manner that discretionary policy give rise to persistence in inflation and unemployment.

3.3 The Effect of Credibility and Transparency on Inflation and Unemployment Persistence

In order to clearly display the magnitudes of the persistence in inflation and unemployment predicted by the model I proceed by simulating a set of disinflationary regime shift under different levels of credibility and transparency. The initial preference parameter is set to equal one (i.e., $\omega_O = 1$). Hence, the monetary authorities assign an equal importance to inflation and unemployment variability. The new regime is characterized by a preference parameter equal to two (i.e., $\omega_N = 2$), indicating that the central bank now perceives inflation variability to be twice as important as that of unemployment. Also, b, $\pi *$, $\overline{U}^n$ and U^* are set equal to 2, 0.5, 6 and 5.25 respectively.[14] The natural rate is assumed to be constant over time. Assuming that one time period is equivalent to a quarter, these values imply an initial quarterly inflation level of 2% and a new long-run inflation equal to 1.25%.

Figure 1(a) and (b) illustrate the relationship between inflation persistence, as measured by the average number of quarterly inflation points reduced per quarter, and the level of credibility and transparency.[15] The level of credibility and transparency are measured by P_0^N and σ_η, respectively. The upward sloping lines in figure 1(a) indicate a clear positive and non-linear relationship between persistency and the initial level of

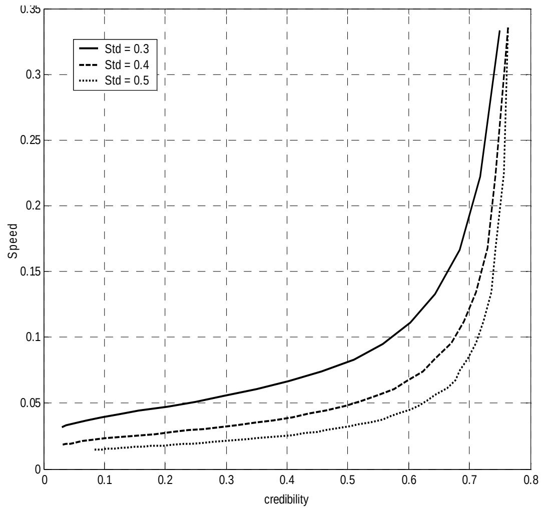
[14]In the next section, I will obtain estimates for a composite of these parameters. These values are chosen such that they approximately match these empirical results. However, since I cannot estimate the parameters individually there is some discretion in selecting the values of b, U^*, ω, and $\overline{U}^n$.
[15] The speed is measured over the period required to complete approximately 80% of the disinflation.

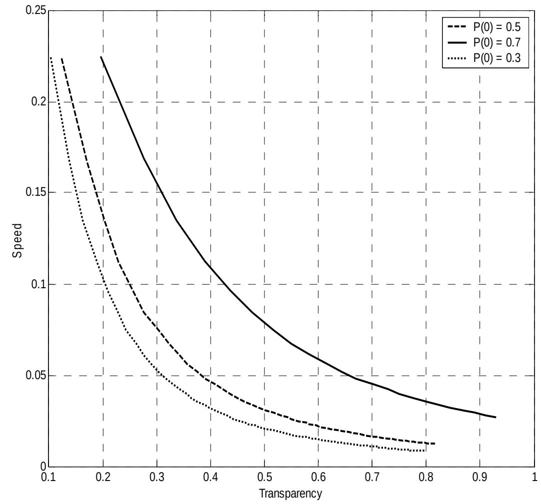
credibility. The nature of the non-linearity implies that there are diminishing returns to credibility. That is, improvements in credibility do not seem to affect the inflation persistence at the lower end of the credibility spectrum as much as at the upper end. Furthermore, the marginal reduction in inflation persistence with respect to increased credibility seems to rise with the level of transparency. Figure 1(b) shows that, given the credibility level, a reduction in transparency will increase the speed of the disinflation and that there are increasing returns to transparency in terms of reduced inflation persistence.

Figure 1(c) and 1(d) illustrate the relationship between the cost of disinflation and the level of credibility and transparency. Disinflation costs are measured by the sacrifice ratio defined as the sum of employment losses over the first five years of the disinflation process divided by the difference between the initial and final inflation rate. The simulations clearly show that unemployment persistence increases with reduced credibility and transparency.[16] Additionally, figure 1(c) and 1(d) indicate that there are diminishing returns to credibility and increasing returns to transparency in terms of employment losses. However, in contrast to the relationship between inflation persistence and credibility, there are significant returns to credibility in terms of reduced employment losses at the lower end of the credibility spectrum.

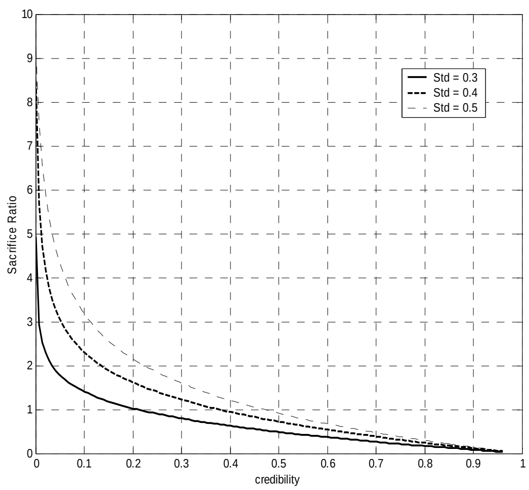
[16] This result is in line with Ball (1995) and Ireland (1995), who also show that the cost of a disinflation is higher under imperfect credibility.

(a) Credibility and Inflation Persistence





(c) Credibility and Unemployment Persistence



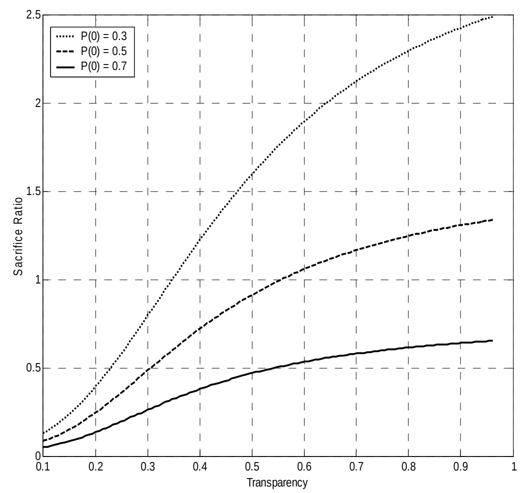


Fig. 1. The speed of the disinflation is measured over the period required to complete approximately 80% of the disinflation. The sacrifice ratio is defined as the sum of unemployment losses (deviation between the actual unemployment and the natural rate of unemployment) over the difference between initial and final inflation. Credibility is measured by the initial probability assigned by the public to the event that the regime shift has taken place. Transparency is measured by σ_η. The three lines in (a) and (b) represent different levels of transparency (i.e., $\sigma_\eta = 0.5, 0.4, 0.3$). The three lines in (c) and (d) represents different levels of credibility (i.e., $P(0) = 0.3, 0.5, 0.7$)

4. Short-Run Dynamics and the Volcker Disinflation

4.1 Regime Shifts and Learning: A Comparison with Ireland's Results

Ireland (1999) tests the hypothesis implied by the BG model that inflation should be positively related to the natural rate of unemployment. Using U.S quarterly data, he shows that the data supports a long-run positive relationship between inflation and unemployment. However, he concludes that an extended model is needed to account for short-run dynamics. In this section, I ask three questions. First, are Ireland's results robust when taking into account the regime shift of 1979. If not, do the results weigh in favor of the model presented in this paper? Second, can the model presented in section 3 provide an insight into why of the BG model fails to explain the short-run dynamics of inflation and unemployment? Finally, can the modified BG model presented in this paper generate the observed inflation and unemployment persistence during the Volcker-disinflation?[17]

Let us first review Ireland's slight modification of the Barro-Gordon model. From equation (6) and (7) it is obvious that both inflation and unemployment dynamics are driven by movements in the natural level of unemployment. Thus, Ireland observe that the only way to explain the rise and fall of inflation during the last three decades is to assume that the natural rate of unemployment increased in the 70s and decreased in the 80s and 90s. Since Ireland cannot reject the null of a unit root in neither unemployment nor inflation it implies that the natural rate of unemployment is non-stationary.[18] He

[17] The quarterly and seasonally adjusted data used in this section are from the Federal Reserve Bank of St. Louis' FRED database. This is the same data used by Ireland. The civilian unemployment rate is used as a measure of the real activity in the economy and inflation is measured by changes in the implicit GDP price deflator.

[18] Irelands uses quarterly data from 1960:1 to 1997:2 and 1970:1 to 1997:2. He cannot reject the null hypothesis of a unit root in either of the samples

imposes such a dynamic structure on the natural rate and shows that it is possible to construct a stationary linear combination of inflation and unemployment by multiplying (7) with $b/_{\omega}(1-k)$ and subtracting it from the expression for the realized inflation (i.e., combining (4) and (6)).

$$\pi_t - \frac{b}{\omega}(1-k)U_t = \pi^* - \frac{b}{\omega}(1-k)\varepsilon_t + \left(1 + \frac{b^2}{\omega}(1-k)\right)\eta_t \qquad (13)$$

Equation (13) suggests that inflation and unemployment should be co-integrated. Indeed, Ireland finds that he can reject the null of no co-integration between inflation and unemployment. On the other hand, the residuals are found to be highly serially correlated which contradicts (13). Table 1(a) shows the results from the Phillips-Ouliaris cointegration test and table 1(b) that of Johansen's cointegration test. The empirical estimates from Ireland's test of co-integration are shown in each of the first rows of the two tables. The second row shows the results when expanding the sample period to include data up to the first quarter of 2001. The estimates of the co-integration vector from regressing inflation on unemployment indicate that $b/_{\omega}(1-k)$ equals 0.1679, while Johansen's cointegration test suggests a value of 0.1704. The coefficient, ρ, obtained from fitting an AR(1) process to the residuals from the inflation-unemployment regression, is estimated to be 0.8725, an indication that the residuals are highly serially correlated.

One major shortcoming in Ireland's analysis is that he completely abstract from potential complications arising from regime shifts. If we assume that a regime shift is represented by a change in the preference parameter ω, then the co-integration vector in (13) should also change. Of course, the most obvious regime shift in the last thirty years is the Volcker-disinflation that occurred in October of 1979.[19] Table 1(a) and 1(b) shows the estimates of Ireland's co-integration vector using quarterly data pre and post the 1979 regime shift.[20] In either sub-sample, I can reject the null of no co-integration.[21] Tables 1(a) and (b) also report the estimates for $b/\omega(1-k)$. The pre-Volker estimates from the Phillips-Ouliaris and Johansen's cointegration tests are 0.2549 and 0.2446 respectively, and the estimates post October 1979 are 0.1301 and 0.1369. Notice that, holding $b(1-k)$ constant these estimates indicate that $\frac{\omega_N}{\omega_O}$ increased, which is consistent with the characterization of a disinflationary regime shift. The point estimates indicates that after 1980, the monetary authorities doubled the weight assigned to inflation volatility.

What about the high degree of serial correlation? Can the model presented in section 3 shed any light on this issue? By multiplying (11) with $b/\omega(1-k)$ and subtracting it from the expression for the realized inflation (i.e., combining (4) and (10)) we have:

$$\pi_t - \frac{b}{\omega}(1-k)U_t = \pi^* + (\theta_{t-1}-1)\frac{b}{\omega}(1-k)kE_{t-1}U_t^n - \frac{b}{\omega}(1-k)\varepsilon_t + \left(1+\frac{b^2}{\omega}(1-k)\right)\eta_t \qquad (14)$$

[19] When conducting a Chow break point test at 1980:1, I can reject the null of no structural break in the relationship between unemployment and inflation.

[20] As mentioned by Ireland (1999), there is evidence that there is a significant break in the time-series dynamics of data on unemployment and inflation around 1970 (King and Watson (1997)). Therefore I do not use data from before 1970.

[21] At a significance level of 5%, I cannot reject the null of a unit root in inflation in either sub-sample. The same is true for unemployment post-1980. However, I only fail to reject the null at a 1% significant level in unemployment pre-1980.

Note that in the long-run, when $\theta_t = 1$, (14) is identical to (13). However, in the transition phase the second term on the right-hand side should indeed create serial-correlation in the residuals when estimating the co-integration vector. Hence, Ireland's results should not come as a surprise if monetary policy lacks credibility and transparency.

Table 1(a): Phillips-Ouliaris Cointegration Test

Sample Period	$b/\omega(1-k)$	ρ	τ	q	Z_τ
1970:1-1997:2	0.1791	0.8709	-2.7603	0	-2.7603**
1970:1-2001:1	0.1679	0.8725	-2.9603	0	-2.9603**
1970:1-1979:4	0.2549	0.7216	-2.4609	0	-2.4609*
1980:1-2001:1	0.1301	0.8474	-2.2922	0	-2.2922**

Table 1(b): Johansen's Cointegration Test

Sample Period	λ_1	λ_2	Normalized Cointegration Vector	$LR = -T\ln(1-\lambda_1)$
1970:1-1997:2	0.1189	0.0050	$\pi_t - 0.1945U_t$	13.6701*
1970:1-2001:1	0.1907	0.0025	$\pi_t - 0.1704U_t$ (0.018)	26.7594**
1970:1-1979:4	0.3081	0.0017	$\pi_t - 0.2446U_t$ (0.023)	14.7979*
1980:1-2001:1	0.2091	0.0153	$\pi_t - 0.1361U_t$ (0.016)	21.2487**

Note: ρ is the coefficient from a regression of the residuals from the inflation-unemployment regression on its own lagged value, τ is the t-statistic for testing the hypothesis that $\rho = 1$. Z_τ is the critical value reported under the heading "case 1" in Hamilton (1994), and q is the lag truncation parameter to form the Newey-West estimator.
* denotes significance at the 5% level
**denotes significance at the 1% level

Despite the simplicity of the framework and the obvious difficulties to assign values to the model's parameters, it would nonetheless be instructive to see whether the model can generate the inflation and unemployment persistence observed during the Volcker disinflation. Let us assume that the Fed assigned equal weight to inflation and unemployment volatility prior to 1980 i.e., $\omega_O = 1$. Since table 1 indicates that the relative weight assigned on inflation volatility doubled after 1980 this would then imply that $\omega_N = 2$. Also, let $b/_{\omega_N}(1-k) \approx 0.125$ and $b/_{\omega_O}(1-k) \approx 0.25$. Using these parameter values, it is possible to derive a set of feasible values for b, and k. I have chosen 2 and 0.875, respectively. Let $\overline{U}^n$ equal 6%, the average unemployment rate over the period 1970-2001, and $\pi^* = 0.5$.[22] Assuming that $\overline{U}^n$ is constant and that the economy is in a long-run equilibrium at time *t*=0, these parameter values implies that the initial inflation and unemployment rate are 2% and 6%, respectively, which is fairly close to the actual unemployment and quarterly inflation rate in the last quarter of 1979 i.e., 2.24% and 6.3%.

Ball (1993) and Blinder (1987) estimate that the Volcker disinflation lasted for approximately 15 quarters i.e., from 1980:1 until 1983:4. Blinder (1987) estimates the sacrifice ratio to 2.1 points of unemployment per point of annual inflation. Ball (1993) estimates the sacrifice ratio in terms of output to be 7.33. Assuming an Okun's Law coefficient of 2.5, this would translate to 2.9 points of unemployment per point of annual inflation. To get a measure of the inflation persistence during the period 1980:1-1983:4 it is informative to look at the average quarterly inflation reduction. Measured over the whole period the average speed of the Volcker-disinflation was approximately 0.091%.[23] Additionally, using the standard deviation of the de-trended inflation during this period as a measure for σ_η gives us a transparency level of 0.39.[24]

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[22] The values assigned to $\overline{U}^n$ and *k* implies that U^* equal 5.25.

[23] After 10 quarters 80% of the disinflation had been achieved at an average speed of 0.115% per quarter.

[24] The trend inflation is estimated by applying the Hodrick-Prescott filter to quarterly data of the implicit GDP price deflator for the period 1970:1-2001:1.

Figure 1(a)-1(d) displays the results from simulating a set of disinflations under different levels of initial credibility and transparency. From figure 1(a) the level of credibility needed to generate an observed inflation persistence of 0.1, given $\sigma_\pi = 0.39$, would be in the neighborhoods of 0.6-0.7. A sacrifice ratio of 2, however, given $\sigma_\pi = 0.39$, would only be possible at very low levels of credibility. Hence, it is significantly harder for the model to generate the disinflation costs as opposed to the inflation persistence observed during the Volcker-disinflation.

4.2 Is there Evidence of a Learning Process?

In this section, I will estimate the relationship between inflation and unemployment taking the learning process into account. Taking the expectations of (11) and substituting it into (10), we can derive the following set of equations:

$$\pi_t = \pi^* + \frac{b}{\omega_N}(1-k)\rho_{t-1}U_t + z_t \tag{15}$$

$$\rho_t = \frac{\theta_t}{k + \theta_t(1-k)} \tag{16}$$

$$z_t = -\, b/\omega_N \,(1-k)\rho_{t-1}\left[U_t - E_{t-1}^{CB}U_t\right] + \eta_t \tag{17}$$

As $\theta_t \to 1$ so will ρ_t.[25] Equation (15) suggests that if learning and credibility is of importance, then Ireland's co-integration vector (13) should suffer from parameter instability. Brown, Durbin, and Evans, (1975) suggest a test based on the cumulative sum of the recursive residuals (also referred to as the CUSUM test) in order to test for

[25] Notice that z_t contains the forecast error of the unemployment rate, which is orthogonal to any variable in the information set Ω_{t-1}^{CB}. Thus, ρ_{t-1} is orthogonal to both the forecast error and the control error. Also, ρ_t have to be stationary or deterministic in order for z_t to have a fixed unconditional variance.

parameter instability. If, for all *t*, the cumulative sum remains between the critical values derived from its asymptotic distribution at time *t*, then we will accept the null hypothesis of stable coefficients. Figure 2 indicates that the null can be rejected for the period following the regime shift in 1979 since the cumulative sum goes outside the area between the two critical lines. However, the null cannot be rejected for the pre-Volcker period.

In order to estimate (15), I will assume that ρ_t follows an AR(1).[26] This assumption makes it possible to define and estimate the following equations using the Kalman filter for time-varying parameters:

$$\pi_t = \alpha + \beta_t U_t + z_t \tag{18}$$

$$\beta_{t+1} - \overline{\beta} = \phi\left(\beta_t - \overline{\beta}\right) + \xi_t \tag{19}$$

where $\alpha = \pi^*$, $\beta_t = \frac{b}{\omega_N}(1-k)\rho_{t-1}$, and $\overline{\beta} = \frac{b}{\omega_N}(1-k)$. This specification allows a shock, ξ_t, to enter directly into the learning process. The shock could be interpreted as information other than last period's inflation rate that affects the learning parameter. The parameter ϕ is a free parameter not related to the underlying theoretical framework, but included as a measure of the speed of the learning process.

[26] When simulating the model it is clear that an AR(1) process imitates the behavior of ρ_t fairly well.

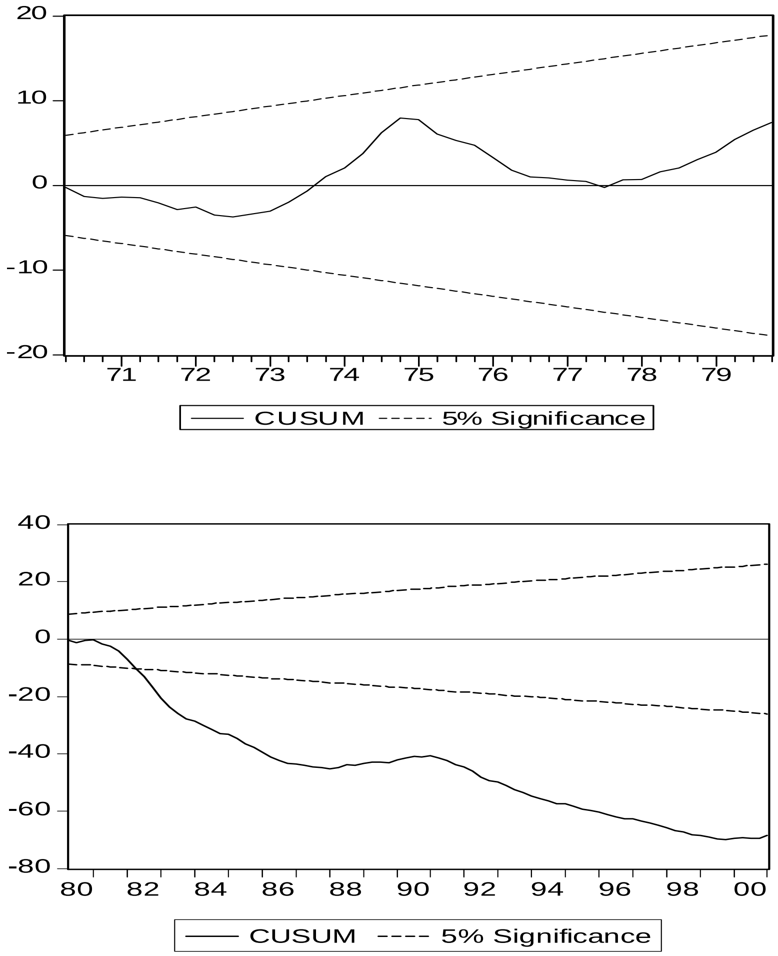


Fig 2. CUSUM test for the periods 1970:1-1979:4 and 1980:1-2001:1

Table 2 shows the results of estimating equation (18) and (19) using quarterly data. The model was estimated with and without a time-invariant constant. The estimates of $b/_{\omega}(1-k)$ differ somewhat from Ireland's co-integration vector estimates. When a time-invariant constant is included the estimate is 0.109 and when excluded it is 0.128. The estimate of the inflation target π^* is 0.24 but not significant. The point estimate would indicate an annual target of around 1%. Both the unconstrained ($\phi = 0.776$) and constrained ($\phi = 0.824$) model suggests that the learning process was relatively slow.

Table 2: Kalman Filter Estimates

Random Coefficient Estimation According to (18) and (19):

Sample	α	$\overline{\beta}$	ϕ	D-W	LL
1980:1-2001:1	0.239 (*0.229*)	0.109 (*0.035*)	0.776 (*0.047*)	2.78	4.29
1980:1-2001:1	- -	0.128 (*0.021*)	0.824 (*0.053*)	2.78	7.63

Note: The standard errors are in parenthesize below the point estimate. D-W is the Durbin Watson statistic and LL stands for log likelihood.

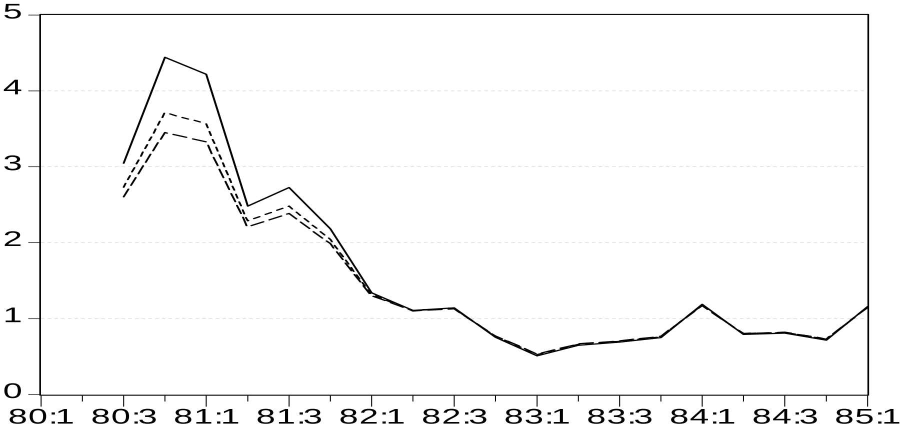
Of course, the parameter that we are most interested in is the learning parameter θ_t. The problem is that in order to derive the learning parameter from the estimates of ρ_t we need to know the value of k. Figures 3(a) and 3(b) show the dynamics of the learning parameter θ_t given k=0.85, 0.875, and 0.9 for the period 1980:1-1985:1.[27] Figure 3 (a) corresponds to the unconstrained model and figure 3(b) corresponds to the constrained model. The figures show that following the regime shift in 1979, θ_t was significantly above one, as we would expect after a disinflationary regime shift. As time evolves, the learning parameter approaches one as predicted by the theoretical model.

Finally, figure 3(c) presents estimates of the learning parameter under the assumption that ρ_t is non-stochastic. In this case the Kalman filter is identical to a recursive OLS estimation over the sample period 1980:1-2001:1. Following the regime shift in 1979, θ_t is well above its long-run level but decreases gradually over time. Although the estimations of the learning parameter in this section are not econometrically rigorous but more of an indicative nature, they clearly supports the existence of learning

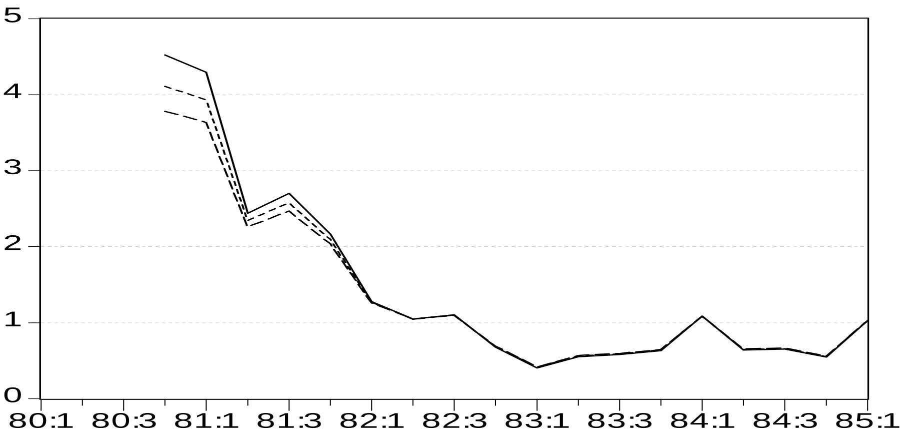
[27] The smooth estimates of ρ_t are not reported here, but can be obtained from the author upon request. The standard errors of the smooth estimates of ρ_t are extremely small since the parameter picks up a lot of the variation in the data.

process.

(a) Unconstrained model



(b) Constrained model



(c) Recursive OLS estimation

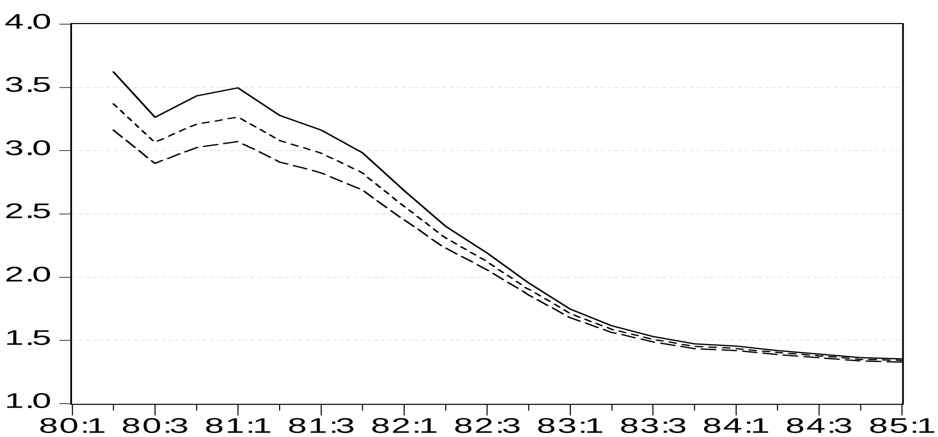


Fig 3. Estimates of the learning parameter

5. Conclusion

The neoclassical proposition that monetary policy does not matter rests on three assumptions: (1) fully flexible prices and wages, (2) rational expectations, and (3) perfect information. The New Keynesian literature relaxes the first assumption by introducing friction in the price/wage setting process, which allows monetary policy to affect the real economy in the short-run. However, several researchers have pointed out that this framework fails to account for the observed persistency in inflation and real activity during disinflationary periods. Much of the current literature on this so-called persistency puzzle has focused on augmenting the nominal contracts models with learning and imperfect credibility (i.e., relaxing the assumption of perfect information). However, one undesirable feature of these learning models is that they assume that the monetary authorities do not behave optimally but instead simply follow an exogenously determined Taylor rule. Hence, the explicit relationship between discretionary policy and inflation and unemployment persistence is disregarded.

This paper presents a modified version of Barro and Gordon's (1983) neoclassical model of discretionary monetary policy. By incorporating imperfect information regarding the true preferences of the monetary authorities and a consequent learning process on the part of the public, I show that imperfect credibility and transparency can, even in the absence of nominal rigidities, generate a substantial amount of persistence in inflation and unemployment following a disinflationary regime shift. This result is due to the failure of discretionary policy to incorporate the impact of credibility and transparency on the dynamics of inflation expectations, which leads to a dynamically inconsistent disinflation characterized by excessive employment losses and persistent inflation. Hence, in its simplest form the model suggests, in sharp contrast to the New Keynesian framework, that long-run persistence in inflation is governed by the persistence in the natural rate of unemployment, but short-run persistence is due to dynamically inconsistent monetary policy coupled with incomplete information.[28]

However, simulations indicate that although the model can easily generate a high degree of inflation persistence, it has more difficulty generating large sacrifice ratios. Interestingly, Taylor (1998) argues that the inclusion of learning or lack of credibility in a rational expectations model of staggered contracts can easily explain the observed disinflations costs, but that such a framework is less likely to generate observed inflation persistence. The answer to this puzzle may be that while nominal rigidities are primarily responsible for the observed employment losses, inflation persistence is largely due to the discretionary nature of monetary policy.

[28] In a previous version of this paper the model was extended to allow the monetary authorities to control the short-term nominal interest rate. I showed that discretionary policy coupled with imperfect credibility and transparency, as expected, also led to a high degree of interest rate persistence following a disnflationary regime shift. Furthermore, if the monetary authorities suffered from sever lack of credibility the nominal interest rate would increase following the regime shift.

Appendix

Defining the Learning Parameter

By substituting (8) into the reaction function of the central bank (5) and assuming that expectations are rational, we derive the two conditional expectations:

$$E_{t-1}^{p}\left[\pi_t \middle| \omega=\omega_N\right]=\pi^*+\frac{b(b^2+\omega_O)}{\omega_O\left(b^2+\omega_N\right)+P_{t-1}^{N}b^2\left(\omega_N-\omega_O\right)}(1-k)E_{t-1}^{p}U_t^{n} \qquad \text{(A.1)}$$

$$E_{t-1}^{P}\left[\pi_t \middle| \omega=\omega_O\right]=\pi^*+\frac{b(b^2+\omega_N)}{\omega_O\left(b^2+\omega_N\right)+P_{t-1}^{N}b^2\left(\omega_N-\omega_O\right)}(1-k)E_{t-1}^{p}U_t^{n} \qquad \text{(A.2)}$$

To simplify the expressions and make the model more tractable we define a time varying parameter θ_t. I will refer to this parameter as the learning parameter and it will be defined as:

$$\theta_t=\frac{\omega_N\left(b^2+\omega_O\right)}{\omega_O\left(b^2+\omega_N\right)+P_t^{N}b^2\left(\omega_N-\omega_O\right)} \qquad \text{(A.3)}$$

From (A.3) it is clear that as P_t^N approaches one, so will θ_t. If there has been a disinflationary regime shift i.e., $\omega_N>\omega_O$, then $\theta_t\geq 1$. On the other hand, if there has been an inflationary regime shift i.e., $\omega_O>\omega_N$, then $\theta_t\leq 1$. It is easy to show that

$$\frac{b}{\omega_O}<\frac{b}{\omega_N}\theta_t<\frac{b}{\omega_N}\ \forall\theta_t \qquad \text{if} \qquad \omega_O>\omega_N$$

and

$$\frac{b}{\omega_O} > \frac{b}{\omega_N}\theta_t > \frac{b}{\omega_N} \quad \forall \theta_t \qquad \text{if} \qquad \omega_O < \omega_N$$

The upper bound (following a disinflationary regime shift) of the learning parameter is thus $\omega_N\left(b^2+\omega_O\right)/\omega_O\left(b^2+\omega_N\right)$ which is less than ω_N/ω_O .

Deriving the Unemployment dynamics

Using the definition of the learning parameter we can derive an expression for the unemployment dynamics following a regime shift. From (A.3) we have that

$$\theta_t - 1 = \frac{b^2\left(1-P_t^N\right)\left(\omega_N-\omega_O\right)}{\omega_O\left(b^2+\omega_N\right)+P_t^N b^2\left(\omega_N-\omega_O\right)} \tag{A.4}$$

The forecast error can be expressed as

$$\begin{aligned}\pi_t - E_{t-1}^P[\pi_t] &= \left(\pi_t - P_{t-1}^N \times E_{t-1}^P[\pi_t|\omega_N]\right) - \left(1-P_{t-1}^N\right)\times E_{t-1}^P[\pi_t|\omega_O] \\ &= \left(1-P_{t-1}^N\right)\times\left(E_{t-1}^P[\pi_t|\omega_N] - E_{t-1}^P[\pi_t|\omega_O]\right) + \eta_t\end{aligned} \tag{A.5}$$

From equation (A.1) and (A.2) we get,

$$E_{t-1}^P[\pi_t|\omega=\omega_O] - E_{t-1}^P[\pi_t|\omega=\omega_N] = \frac{b\left(\omega_N-\omega_O\right)}{\omega_O\left(b^2+\omega_N\right)+P_{t-1}^N b^2\left(\omega_N-\omega_O\right)}(1-k)E_{t-1}^P\left[U_t^n\right] \tag{A.6}$$

Thus substituting (A.6) into (A.5) and using (A.3) we have,

$$\pi_t - E_{t-1}^P[\pi_t] = -\frac{1}{b}(\theta_{t-1} - 1)(1-k)E_{t-1}^P[U_t^n] + \eta_t \tag{A.7}$$

Equation (A.7) explicitly shows that the public commit systematical forecast errors after a regime shift has taken place. Ex-post it will appear as though the inflation expectations are lagging behind the realized inflation. Finally, substituting (A.7) into the expectation augmented Philips curve we get equation (11) which describes the short-run dynamics of the unemployment rate.

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