The Clash of Central Bankers with Labor Market Insiders, and the Persistence of Inflation and Unemployment

by
George Alogoskoufis*

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Abstract

This paper analyzes the implications of monetary policy for the dynamic behavior of inflation, in a "natural" rate model characterized by endogenous unemployment persistence. We present evidence for the main industrial economies which suggests that inflation displays persistence which is of the same order of magnitude as the persistence of deviations of unemployment from its "natural" rate. We provide a theoretical explanation of this fact based on a model of the dynamic interactions between central bankers and labor market insiders. The clash in the objectives of central bankers and labor market insiders is what causes both inflation and unemployment to display the same persistence in this model. The analysis suggests that inflation persistence could be addressed in a welfare improving way, if central banks adopted monetary policy rules that targeted unanticipated changes in unemployment rates instead of deviations of unemployment from its "natural" rate.

Keywords: unemployment persistence, inflation, monetary policy, insiders outsiders, central banks

JEL Classification: E3, E4, E5

* Fletcher School, Tufts University, Medford MA 02155, USA, and Athens University of Economics and Business, 76 Patission street, GR-10434, Athens, Greece. *Email*: alogoskoufis@me.com *Web Page*: alogoskoufisg.com

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The analysis of monetary policy usually focuses on policy rules that seek to stabilize inflation around a low inflation target and unemployment around its natural rate, even if the natural rate of unemployment is inefficiently high. As demonstrated by Kydland and Prescott (1977) and Barro and Gordon (1983), if central banks seek to use monetary policy to reduce unemployment below its natural rate, the outcome is a positive steady state inflation bias, as the inflationary expectations of labor market participants rise to ensure that the central bank has no incentive to systematically raise inflation above inflationary expectations.

Delegating monetary policy to an independent central banker who does not seek to reduce unemployment below its natural rate, as first suggested by Rogoff (1985), can address this steady state inflation bias problem, and still allow a central bank to seek to stabilize deviations of unemployment from its natural rate in response to unanticipated shocks.

The present paper analyzes monetary policy rules in a dynamic stochastic model of the Phillips curve, characterized by endogenous unemployment persistence. It is shown that, in the presence of persistent deviations of unemployment from its natural rate, all time consistent contingent monetary policy rules will result in inflation persistence. Furthermore, the results of the analysis suggest that, under such rules, the degree of persistence of inflation will be the same as that of unemployment.

We first present evidence from the main industrial economies, which suggests that inflation rates do indeed display the same degree of persistence as deviations of unemployment rates from their natural rates. This evidence corroborates previous findings on the persistence of unemployment and inflation, when either variable is analyzed separately, but also suggests a previously overlooked close association between the degrees of persistence of inflation and unemployment.

We put forward a theoretical model which provides an explanation for these empirical facts. The explanation rests on a clash between the objectives of central bankers and labor market insiders. Central bankers seek to minimize deviations of inflation from target, and unemployment from its natural rate. The wage setting behavior of labor market insiders results in persistent deviations of unemployment from its natural rate. In rational expectations equilibrium under an ?optimal? time consistent contingent policy rule, unemployment persists, due to the wage setting behavior of insiders, and inflation also persists, as central banks use monetary policy and inflation in order to counteract the persistent deviations of unemployment from its natural rate.

The main distinguishing characteristic of the model put forward in this paper is a *dynamic insider outsider version of the Phillips Curve*, which accounts for the persistence of unemployment following nominal and real shocks. This model combines and extends two strands of the literature.

The first strand is the Gray-Fischer model of predetermined nominal wages, according to which nominal wages are set periodically, and remain fixed between periods. Because shocks to inflation are not known when nominal wages are set, unanticipated inflation reduces real wages and causes employment to increase along a downward sloping labor demand curve.[1]

The second strand of the literature is the insider-outsider theory of wage determination of Lindbeck and Snower (1986), Blanchard and Summers (1986), Gottfries and Horn (1987) and Gottfries (1992). According to this theory, there is an asymmetry in the wage setting process between insiders, who already have jobs, and outsiders who are seeking employment. outsiders are disenfranchised from the labor market and cannot affect wage determination. Wages are set by insiders, who seek to maximize the expected real wage consistent with their own employment, and are not concerned with the employment of outsiders.

The two strands were first combined by Blanchard and Summers (1986), who alluded to the dynamics of insider membership to explain the gradual adjustment of employment and the persistence of unemployment following unanticipated shocks. Their argument was that ?shocks that lead to reduced employment change the number of insiders and thereby change the subsequent equilibrium wage rate, giving rise to hysteresis?. Thus, in their model unemployment displays endogenous persistence following nominal and real shocks. In the original Gray (1976) and Fischer (1977) models the deviations of unemployment from its natural rate were not persistent. Such deviations only lasted for one period in the one period contract model of Gray (1976), and for two periods in the two period contract model of Fischer (1977).

Our model in fact extends the Blanchard and Summers setup, to a linear quadratic setup of full intertemporal optimization on the part of insiders. We thus derive a dynamic stochastic model of the Phillips curve, in which unanticipated shocks to inflation and productivity have persistent effects

[1] In the Gray (1976) model, the one we utilize, nominal wages are fixed in the beginning of each period, whereas in the Fischer (1977) model they are fixed in the beginning of alternate periods.

on unemployment. These effects are fully compatible with forward looking behavior on the part of labor market insiders who determine nominal wages.

The number of insiders in each period depends on a exogenous number of core employees, with long term ties to existing firms, but also on all the employees of the firm in the preceding period. Current insiders determine the maximum wage that is expected to keep themselves in employment, but also realize that changes to employment will affect the future number of insiders, and will thus affect future wages. Thus, they are assumed to take expected future employment into account in their periodic wage setting decisions. As a result, current wages depend not only on the current number of insiders, which is a function of past employment, but also on the expected future number of insiders, which depends on current and expected future employment. Hence, the persistence of employment and unemployment is shown to depend on both past employment and unemployment, and expectations about their future evolution.

The *dynamic stochastic Phillips curve* that we derive provides an alternative to the standard *new keynesian Phillips Curve*, and suggests an alternative source of unemployment persistence, compared to new keynesian models, whose main explanation of persistence relies on persistent monetary and real shocks, and staggered price and wage contracts.[2]

In the model of this paper, the propagation mechanism that causes unanticipated nominal and real shocks to produce persistent deviations of unemployment from its natural rate is the gradual adjustment of employment to shocks, and not the staggered adjustment of wages and prices. Nominal wages are assumed to be fixed only for one period in our model, and are assumed to be renegotiated every period on the basis of new information. Thus, nominal wage stickiness would not be able to account for the persistent unemployment and output effects of nominal shocks in the absence of the gradual adjustment of employment.

The distortions that matter for the fluctuations of unemployment and other real variables in our model arise in the labor market, because of one period nominal wage contracts, and the market power of insiders in the wage determination process. The product market is assumed competitive, although

[2]See Gali (2008), (2011a,b) for *new keynesian* models of aggregate fluctuations in the presence of Calvo (1983) staggered price and wage contracts. In fact, since the standard new keynesian model fails to account adequately for the persistence of unemployment, it too has been augmented recently to take the behavior of insiders in the labor market into account. See Gali (2016).

it would be relatively straightforward to add product market imperfections as well.[3]

We first derive the *optimal time consistent, contingent monetary policy rule*, by assuming that the central bank minimizes an inter-temporal quadratic loss function that depends on deviations of inflation from a fixed inflation target, and unemployment from its natural rate. Even under such a contingent monetary policy rule, productivity shocks cannot be fully neutralized by monetary policy. Since productivity shocks are supply shocks, and their real effects can only be partially offset through unanticipated inflation, there is a tradeoff between deviations of inflation from target, and unemployment from its natural rate, even under an ?optimal? contingent monetary policy rule.

In addition, because of the endogenous persistence of deviations of unemployment from its natural rate, the inflation rate associated with this rule also displays persistence around the inflation target of the monetary authorities. The persistence of inflation arises from the fact that the central bank uses inflation in order to reduce deviations of unemployment from its natural rate, which, because of the behavior of insiders, displays endogenous persistence. These incentives of the central bank are anticipated by the wage setting insiders, who base their inflationary expectations on past deviations of unemployment from its natural rate, and therefore neutralize the attempts of the monetary authorities to effectively smooth these deviations. Thus, even under a contingent monetary policy, the resulting persistence in the fluctuations of the inflation rate does not affect the path of unemployment. It is only the unanticipated part of the inflation rate that can affect unemployment in this model.

The persistence of inflation in the presence of endogenous unemployment persistence arises in this model for the same reasons as the inflationary bias

[3]In order to explain unemployment persistence, Gali (2016) also proceeds to augment the standard new keynesian model by using a model of insiders and outsiders. He uses the original Blanchard and Summers (1986) specification of the objective of insiders in the labor market. However, the resulting model becomes analytically intractable, and can only be simulated to examine the properties of alternative monetary policy rules. The model in this paper differs from the Gali model, in that it relies on forward looking insiders, one period nominal wage contracts, instead of staggered wage contracts, full price flexibility, instead of staggered pricing, and competitive instead of monopolistically competitive markets. Because the present model is simpler and more parsimonious, it is analytically tractable. Yet, in most respects, it has very similar predictions about aggregate fluctuations, as an extended new keynesian model with additional distortions.

in the Kydland and Prescott (1977) and Barro and Gordon (1983) models of the natural rate, when the central bank systematically seeks to reduce unemployment below the natural rate. To the extent that the short term employment objectives of wage setters and the central bank differ, with the central bank seeking to minimize persistent deviations of unemployment from its natural rate, the only way for wage setters to ensure that the monetary authorities will follow the expected policy, is to raise their expectations of inflation to the level that will ensure that the central bank has no incentive to deviate from the expected policy. In this way, the expected policy becomes time consistent. It is exactly this mechanism, which is responsible for the persistence of inflation when there is endogenous unemployment persistence. As a result, in the time consistent equilibrium under a contingent monetary policy rule, both the persistence of deviations of inflation from the central bank target, and the persistence of deviations of unemployment from its natural rate will imply social costs.

The lack of credibility that results in inflation persistence can be addressed by either pre-commitment or reputational mechanisms, that would support policy rules other than the optimal time consistent contingent rule. We examine two forms of such rules that do away with the problem of inflation persistence.[4]

One is a time inconsistent non contingent rule that makes inflation the sole objective of monetary policy. This would imply pre-commitment to achieving only an inflation objective. Such a non contingent policy would result in non persistent inflation, as expected inflation would always be equal to the target of the monetary authorities. However, in the presence of monetary policy shocks and productivity shocks, such a policy would result in a sub-optimally high variance of the persistent deviations of unemployment from its natural rate.

The second is a time inconsistent contingent rule, which allows monetary

[4]There is still a lot of confusion in the monetary policy literature regarding the tags assigned to alternative policy rules. A number of authors refer to a time consistent contingent policy rule as *discretionary policy*, and the time inconsistent policy based on pre-commitment as a *rules based policy*. Yet, both types of policy rely on rules. Game theoretic concepts such as Markov perfect equilibrium with or without pre-commitment have also been used to discriminate between different types of policy rules. In what follows we use the terms *time consistent versus time inconsistent*, to indicate whether there is no short run incentive to deviate from the rule or whether there is such an incentive, and *contingent versus non contingent* policy rules, to indicate whether the rules are state dependent or not.

policy to respond to innovations, i.e unanticipated changes, to unemployment rates, instead of deviations from the natural rate. Such a rule, could potentially be welfare improving relative to the ?optimal? time consistent contingent rule, as it does away with inflation persistence and its costs, without a countervailing increase in the variance of deviations of unemployment from its natural rate.

We demonstrate that, in the context of our model, the optimal time consistent contingent policy, despite its shortcomings, dominates the policy of pre-committing solely to the inflation target. Hence, we interpret the observed persistence of inflation as the side effect of the fact that central banks follow time contingent monetary policy rules, in a world in which their objectives clash with the objectives of labor market insiders.

However, we also argue in favor of welfare improving contingent rules, which would result in non persistent inflation rates. Such rules, require central banks to respond only to unanticipated changes in unemployment rates, and could also be supported by either pre-commitment or reputational mechanisms.

The rest of the paper is as follows: In section 1 we present evidence for the main industrial economies, regarding the persistence of unemployment and inflation. On the basis of this evidence one cannot reject the hypothesis that inflation displays the same degree of persistence as deviations of unemployment from its natural rate. In section 2 we present our dynamic stochastic model of the Phillips curve, based on the behavior of insiders in the labor market. This model accounts for unemployment persistence. In section 3 we derive the implications of the optimal contingent inflation policy and the non-contingent policy of full commitment to the inflation target. Under an optimal contingent monetary policy rule inflation persists to the same extent as deviations of unemployment from its natural rate and the rule is time consistent. Under a non contingent rule of full commitment to an inflation target the persistence of inflation disappears, but the variance of deviations of unemployment from its natural rate increases substantially. The contingent policy rule is shown to clearly dominate the non-contingent rule. In section 4 we discuss welfare improving time inconsistent contingent rules that require pre-commitment, and would eliminate inflation persistence. The last section sums up our conclusions.

1 The Persistence of Unemployment and Inflation in the G-7 Economies

In this section we present evidence on the persistence of unemployment and inflation in the main industrial economies(the G-7). The evidence is consistent with previous findings, but highlights a new empirical fact: the persistence of inflation is the same as the persistence of deviations of unemployment from its natural rate in all of the G-7 economies.[5]

In the evidence that we present below, the natural rate of unemployment is approximated by a Hodrik Prescott (1997) filter. With regard to steady state inflation rates, we allow these to differ between the Bretton Woods period, 1952-1971, the first period of flexible exchange rates 1972-1982, and the post-Volcker period, 1983-2014, by introducing relevant dummy variables.

It turns out, from the evidence presented below, that with the exception of Japan, there is no difference in steady state inflation between the Bretton Woods period and the post-Volcker period, but that there is a significant difference between these periods and the first ten years of flexible exchange rates 1972-1982, which are characterized by a significantly higher average inflation rate than the other two sub-periods.

Our results for the main industrial economies of the USA, Japan, Germany, France, Italy, the United Kingdom and Canada, using annual data for the post war period are presented in Tables 1 and 2. Table 1 presents the results for deviations of unemployment from its natural rate, modeling the natural rate through a Hodrik Prescott (1997) filter. Table 2 presents the results for deviations of inflation from fixed targets, allowing for different targets between 1972-82 and the other two sub-periods.

<u>Insert Tables 1 and 2 about here</u>

[5]With regard to unemployment, the early empirical studies of Blanchard and Summers (1986), Alogoskoufis and Manning (1988), and Layard, Nickell and Jackman (1991), among many others, suggest that deviations of unemployment from its natural rate display significant persistence mainly in Europe, but also in most of the other industrial economies. The post war shift in the persistence of inflation was initially highlighted and linked to monetary policy rules by Alogoskoufis and Smith (1991) and Alogoskoufis (1992). The extensive subsequent literature is surveyed in the more recent study by Gadea and Mayoral (2006), who provide estimates of inflation persistence for most OECD countries. However, to our knowledge, few studies have explicitly linked the persistence of inflation to the persistence of unemployment.

A number of observations are worth making concerning the estimates in Tables 1 and 2.

First, both deviations of unemployment from its natural rate and deviations of inflation from a constant target appear to be 2nd order and not 1st order autoregressive processes. We thus calculate the degree of persistence of unemployment and inflation as the sum of the estimated parameters on the two lagged dependent variables, and report the relevant standard error of estimate of this sum.

Second, neither deviations of unemployment from its Hodrik Prescott natural rate, nor deviations of inflation from a constant target appear to be characterized by a unit root. The relevant ADF statistics do not indicate the presence of a unit root at conventional levels of significance for any of the countries concerned. This is somewhat surprising in view of previous results, especially the results of Blanchard and Summers (1986). Using the Hodrik Prescott filter for the natural rate of unemployment results essentially removes the unit root, attributing it to the natural rate of unemployment. Thus, fluctuations of unemployment rates around their natural rates appear to be stationary stochastic processes.

Third, the degree of persistence, i.e the sum of the two autoregressive parameters, is positive and statistically significant for all countries, both in the unemployment and the inflation equations. The degree of persistence of deviations of unemployment from their natural rate ranges from 0.311 in the case of the USA, to 0.596 in the case of Italy. It is about one half for the remaining countries. The degree of persistence of inflation ranges from 0.374 in the case of France, to 0.595 in the case of Italy. For the remaining countries it is also about one half. Thus, on the basis of these estimates, there does not seem to be prima facie evidence of significant differences in the degree of persistence of deviations of unemployment from its natural rate and deviations of inflation from the target of the monetary authorities.

This is confirmed by joint estimation of the unemployment and the inflation equations. The hypothesis of the same degree of persistence of deviations of unemployment and inflation cannot be rejected for any of the G-7 countries at conventional significance levels. The relevant Wald tests, for an equal degree of persistence of unemployment and inflation, when the unemployment and inflation equations are estimated jointly as a system, are equal to 0.24 for the USA, 0.05 for Japan, 0.09 for Germany, 0.43 for France, 0.0001 for Italy, 0.37 for the UK and 0.005 for Canada. The critical values of ?2(1) are 6.635 at the 1% significance level, 3.841 at the 5% significance level and 2.706

at the 10% significance level. Thus, the hypothesis that unemployment and inflation display the same degree of persistence in all of the G-7 economies in the post war period cannot be rejected at conventional significance levels.

Fourth, there appears to have been a significant upward shift in inflation following the collapse of the Bretton Woods system and the initial shift to flexible exchange rates. However, the intercept in the inflation equations has been roughly constant in the rest of the post war period, with the exception of Japan. On the basis of the estimates in Table 2, steady state inflation has been around 2.5% percent per annum in the USA, 2.1% per annum in Germany, 2.2% per annum in Canada, and slightly higher in France, Italy and the UK. For the case of Japan, one cannot reject the hypothesis that in the post-1982 period steady state inflation in Japan has actually been zero.

To summarize, although there appear to be differences in the degree of unemployment persistence among the industrial economies, these differences are relatively small. In all cases, the degree of unemployment persistence is mirrored in the degree of inflation persistence.

In the rest of this paper we present a dynamic stochastic macro model in which the persistence of unemployment leads to a persistent inflation rate. This model, provides a theoretical explanation for the stylized facts regarding the persistence of inflation and unemployment, in a setting of dynamic interactions between central bankers and labor market insiders.

2 Insiders and Outsiders in a Dynamic Stochastic Model of the Phillips Curve

Consider an economy consisting of competitive firms, indexed by i, where $i \in [0, 1]$. The production function of firm i is given by,

$$Y(i)_t = A_t L(i)_t^{1-\alpha} \tag{1}$$

where $Y(i)$ is output, A is exogenous productivity, and $L(i)$ is employment. t is a time index, where $t = 0, 1, \ldots$.

Employment is determined by firms, who maximize profits, by equating the marginal product of labor to the real wage. Thus, employment is determined by the marginal productivity condition that,

$$(1-\alpha)A_t L(i)_t^{-\alpha} = \frac{W(i)_t}{P_t} \tag{2}$$

where $W(i)$ is the nominal wage of firm i, and P is the price for the product of firm i. Since the product market is assumed competitive, all firms face the same price, and $P(i) = P$ for all firms.

In log-linear form, (1) and (2) can be written as,

$$y(i)_t = a_t + (1-\alpha)l(i)_t \tag{3}$$

$$l(i)_t = \bar{l} - \frac{1}{\alpha}(w(i)_t - p_t - a_t) \tag{4}$$

where, $\bar{l} = \frac{\ln(1-\alpha)}{\alpha}$.

Lowercase letters denote the logarithms of the corresponding uppercase variables. (3) determines output as a positive function of employment and the stochastic shock to productivity, and (4) determines employment as a negative function of the deviations of real wages from productivity.

2.1 Wage Setting and Employment in an Insider Outsider Model

Nominal wages are set by insiders in each firm at the beginning of each period, before variables, such as current productivity and the current price level are known. Nominal wages remain constant for one period, and they are reset at the beginning of the following period. Thus, this model is characterized by one period nominal wage stickiness of the Gray (1976), Fischer (1977) variety. Employment is determined ex post by the firm, given the contract wage, the actual price level and actual productivity.

The number of insiders, who at the beginning of each period determine the contract wage, is assumed endogenous, as it depends on past employment. The objective of insiders in each firm is to set the highest possible path for nominal wages, which, given their rational expectations about the future price level and productivity, will minimize deviations of expected employment from the expected path of their employment target. This target is a weighted average of all those who were employed in period $t-1$, and an exogenous number of *core* employees in each firm. Thus, this model is characterized by a state dependent pool of insiders, as in Blanchard and Summers (1986). The employment target in period t is determined by,

$$\bar{n}(i)_t = \theta l(i)_{t-1} + (1-\theta)\,\bar{n}(i) \tag{5}$$

where $l(i)_{t-1}$ is the number of those who were actually employed in the previous period, and $\bar{n}(i)$ is the logarithm of the number of core employees, assumed exogenous. θ is the weight of those recently employed relative to core employees in the employment target of insiders. This formulation is the one proposed by Blanchard and Summers (1986).

The expectations on the basis of which wages are set depend on information available until the end of period $t-1$, but not on information about prices and productivity in period t. On the basis of the above, we assume that the objective of wage setters is to choose the path of maximum wages that would minimize deviations of the expected employment path, from the employment target of insiders.

This can be modeled as a maximin problem. Insiders are assumed to choose the expected employment path that minimizes deviations from their target, and select the maximum wage path that satisfies their optimal employment path subject to the labor demand curve. Thus, the problem can be formalized as choosing the path of current and expected future wages which minimizes the following quadratic inter-temporal loss function,

$$\min E_{t-1} \sum_{s=0}^{\infty} \beta^s \frac{1}{2}\left(l(i)_{t+s} - \bar{n}\,(i)_{t+s}\right)^2 \tag{6}$$

subject to the sequence of labor demand equations (4) and employment targets $\bar{n}(i)_t$ as defined in (5). $\beta = \frac{1}{1+\rho} < 1$ is the discount factor, with ρ being the pure rate of time preference. As can be seen from (6), outsiders, i.e the unemployed, have no influence on the wage setting process.

We shall assume that the total number of core employees in the economy is always strictly smaller than the labor force. This assumption ensures that the natural rate of unemployment is strictly positive. We thus assume that,

$$\int_{i=0}^{1} \bar{n}(i)di = \bar{n} < n \tag{7}$$

From the first order conditions for a minimum of (6), wages are set at the maximum level which ensures that expected employment for each firm satisfies,

$$E_{t-1}l(i)_t = \frac{\beta\theta}{1+\beta\theta^2}E_{t-1}l(i)_{t+1} + \frac{\theta}{1+\beta\theta^2}l(i)_{t-1} + \frac{(1-\beta\theta)(1-\theta)}{1+\beta\theta^2}\,\bar{n}(i) \tag{8}$$

The implied contract wage can be derived by using the labor demand (marginal productivity) condition (4) to substitute for employment in (8).

Integrating over i, expected aggregate employment must then satisfy,

$$E_{t-1}l_t = \frac{\beta\theta}{1+\beta\theta^2}E_{t-1}l_{t+1} + \frac{\theta}{1+\beta\theta^2}l_{t-1} + \frac{(1-\beta\theta)(1-\theta)}{1+\beta\theta^2}\,\bar{n} \tag{9}$$

(9) is the same as (8) without the i index.

Wage contracts that satisfy (9) encompass Gray-Fischer contracts and Blanchard-Summers contracts. Thus, our model is more general than the Gray-Fischer model and slightly more general than the Blanchard-Summers model.

With Gray-Fischer contracts, $\theta = 0$, as past employment does not exert any separate influence in the wage setting process. Only core employees would matter in Gray-Fischer type contracts. Setting $\theta = 0$ in (9), nominal wages in Gray-Fischer contracts would be set at the maximum level which ensures that,

$$E_{t-1}l_t = \bar{n}$$

On the other hand, with Blanchard-Summers contracts, there is no consideration of the effects of current contracts on expected employment beyond period t. This is equivalent to setting $\beta = 0$ in (9), i.e with myopic behavior. Setting $\beta = 0$ in (9) implies that nominal wages would be set in order to ensure that,

$$E_{t-1}l_t = \theta l_{t-1} + (1-\theta)\,\bar{n}$$

(9b) is identical to equation (3.2) in Blanchard and Summers (1986). Nominal wages with Blanchard-Summers contracts would be set at the maximum level which ensures that expected employment equals a weighted average of core employees, and those recently employed, without consideration for the effects on future employment.

In our more general dynamic model, wages are set at the maximum level which ensures that expected employment in period t is given by (9), which also depends on expected employment in period $t+1$. This is because expected employment at t will affect the number of insiders who will negotiate wages for period $t+1$. Thus, in our model, insiders are forward looking, in that they set nominal wages in order to achieve an employment target which depends on core employees, those previously employed, but also on those expected to be employed in the future, as expected future employment will affect future wage setting behavior.

2.2 Wage Determination, Unemployment Persistence and the Phillips Curve

Subtracting (9) from the log of the labor force n, after some rearrangement we get,

$$E_{t-1}u_t = \frac{\beta\theta}{1+\beta\theta^2}E_{t-1}u_{t+1} + \frac{\theta}{1+\beta\theta^2}u_{t-1} + \frac{(1-\beta\theta)(1-\theta)}{1+\beta\theta^2}\,\bar{u} \tag{10}$$

where, $u_t \simeq n - l_t$ is the unemployment rate, and $\bar{u} \simeq n - \bar{n} > 0$ is the natural unemployment rate. The natural rate of unemployment in this model is defined in terms of the difference between the labor force and the number of core employees in the labor market. This is the equilibrium rate towards which the economy would converge in the absence of shocks.

It is also worth noting from (10) that if recent employees had no influence in the wage setting process and only core employees mattered, $\theta = 0$ and expected unemployment would always be equal to the natural rate.

To solve (10) for expected unemployment, define the operator F, as,

$$F^s u_t = E_{t-1}u_{t+s} \tag{11}$$

We can then rewrite (10) as,

$$\left((1+\beta\theta^2)F^0 - \beta\theta F - \theta F^{-1}\right)u_t = (1-\beta\theta)(1-\theta)\,\bar{u} \tag{12}$$

(12) can be rearranged as,

$$-\beta\theta F^{-1}\left(F^2 - \frac{1+\beta\theta^2}{\beta\theta}F + \frac{1}{\beta}\right)u_t = (1-\beta\theta)(1-\theta)\,\bar{u} \tag{13}$$

It is straightforward to show that if $0 < \beta < 1$ and $0 < \theta < 1$ and finite, the characteristic equation of the quadratic in the forward shift operator (in large brackets) has two distinct real roots, which lie on either side of unity. The two roots satisfy,

$$\lambda_1 + \lambda_2 = \frac{1+\beta\theta^2}{\beta\theta}, \lambda_1\lambda_2 = \frac{1}{\beta} \tag{14}$$

Using (14), and assuming that λ_1 is the smaller root, we can rewrite (13), as,

$$(1-\lambda_1 F^{-1})(F-\lambda_2)u_t = -\frac{(1-\beta\theta)(1-\theta)}{\beta\theta}\,\bar{u} \tag{15}$$

The solution of (15) under rational expectations is given by,

$$E_{t-1}u_t = \lambda_1 u_{t-1} + (1-\lambda_1)\,\bar{u} \tag{16}$$

(16), which is the rational expectations solution of (10), determines the path of the ex ante expected unemployment rate, implied by the wage setting behavior of insiders.

Actual unemployment is determined through the employment decisions of firms, after information about prices, productivity and other shocks has been revealed.

Integrating the labour demand function over the number of firms i, aggregate labor demand and employment is given by,

$$l_t = \bar{l} - \frac{1}{\alpha}(w_t - p_t - a_t) \tag{17}$$

Subtracting the aggregate employment equation (17) from the log of the labor force n, actual unemployment is determined by,

$$u_t = n - \bar{l} + \frac{1}{\alpha}(w_t - p_t - a_t) \tag{18}$$

Taking expectations on the basis of information available at the end of period $t-1$, the wage is set in order to make expected unemployment equal to the expression in (16), which defines the unemployment rate consistent with the employment objective of labor market insiders.

From (18), the wage is thus set in order to satisfy,

$$w_t = E_{t-1}p_t + E_{t-1}a_t + \alpha\left(E_{t-1}u_t - n + \bar{l}\right) \tag{19}$$

where $E_{t-1}u_t$ is determined by (16).

Substituting (19) for the nominal wage in (18), and using (16), the unemployment rate evolves according to,

$$u_t = \lambda_1 u_{t-1} + (1-\lambda_1)\,\bar{u} - \frac{1}{\alpha}(p_t - E_{t-1}p_t + a_t - E_{t-1}a_t) \tag{20}$$

From (20), unemployment is equal to expected unemployment, as determined by the behavior of insiders in the labor market, and depends negatively on unanticipated shocks to the price level and productivity, which shift labor demand by altering the relationship between ex post real wages and productivity. It is these shocks to the price level and productivity that cause aggregate fluctuations in this model.

We can express (20) in terms of inflation, by adding and subtracting the lagged log of the price level in the last parenthesis. Thus, (20) takes the form of a *dynamic, stochastic, expectations augmented Phillips curve.*

$$u_t = \lambda_1 u_{t-1} + (1-\lambda_1)\,\bar{u} - \frac{1}{\alpha}(\pi_t - E_{t-1}\pi_t + a_t - E_{t-1}a_t) \tag{21}$$

where π is the inflation rate.

Unanticipated positive shocks to inflation reduce unemployment by a factor which depends on the elasticity of labor demand with respect to the real wage, as unanticipated inflation reduces real wages. Unanticipated positive shocks to productivity reduce unemployment, as they reduce the difference between real wages and productivity and increase labor demand. Negative shocks have symmetrically opposite effects.

(21) can be expressed in terms of deviations of unemployment from its natural rate, as,

$$u_t - \bar{u} = \lambda_1(u_{t-1} - \bar{u}) - \frac{1}{\alpha}(\pi_t - E_{t-1}\pi_t + a_t - E_{t-1}a_t) \tag{22}$$

From (22), deviations of unemployment from its natural rate display persistence, and depend negatively on unanticipated shocks to inflation and productivity, as these cause a discrepancy between real wages and productivity, due to the fact that nominal wages are predetermined in the beginning of every period.

It can easily be confirmed from (22) that following a shock to inflation or productivity, unemployment will only converge gradually back to its natural rate, with the speed of adjustment being $(1-\lambda_1)$ per period.

It is also straightforward to show that an increase in θ, the relative weight of recent employees in the wage setting process, results in an increase in λ_1, the coefficient that determines the persistence of unemployment. From the conditions which define the two roots, it follows that,

$$\frac{\partial \lambda_1}{\partial \theta} = \left(\frac{\lambda_1}{\theta}\right)^2 \frac{1-\beta\theta^2}{1-\beta\lambda_1^2} > 0$$

Thus, the higher the weight of recent employees relative to core employees in the wage setting process, the higher the persistence of unemployment. The reason is that it is the difference between recent and core employees that cause deviations of unemployment from its natural rate to persist in this model. It is also straightforward to show that as θ tends to unity, that is if recent employees are the only ones affecting the wage setting process, λ_1 tends to unity, and unemployment displays *hysteresis*. In effect there is no natural rate if $\theta = 1$.

2.3 The Relation between Output and Unemployment

The persistence of employment and unemployment, will also be translated into persistent output fluctuations.

Aggregating the firm production functions (3), the aggregate production function can be written as,

$$y_t = a_t + (1-\alpha) l_t \tag{23}$$

Adding and subtracting $(1-\alpha)(n-\bar{n})$, the production function can be written as,

$$y_t = \bar{y}_t - (1-\alpha)(u_t - \bar{u}) \tag{24}$$

where,

$$\bar{y}_t = (1-\alpha)\,\bar{n} + a_t \tag{25}$$

is the log of the natural level of output.

(24) is an Okun (1962) type of relation, which suggests that fluctuations of output around its natural level will be negatively related to fluctuations of the unemployment rate around its own natural rate.

From (23) and (22), deviations of output from its natural level will be determined by,

$$y_t - \bar{y}_t = \lambda_1 (y_{t-1} - \bar{y}_{t-1}) + \frac{1-\alpha}{\alpha}(\pi_t - E_{t-1}\pi_t + a_t - E_{t-1}a_t) \tag{26}$$

(26) shows that deviations of output from its natural level, also display persistence, because of the persistence of employment and unemployment.

(26) is the dynamic output supply function in this model. Deviations of output from its natural level depend positively on unanticipated shocks to inflation and productivity, as these cause a discrepancy between real wages and productivity, due to the fact that nominal wages are predetermined. Unanticipated shocks to inflation reduce real wages and induce firms to increase labor demand, employment and output. Unanticipated shocks to productivity, given the inflation rate, cause an increase in productivity relative to real wages, and also cause firms to increase labor demand, employment and output, beyond their natural levels. On the other hand, anticipated shocks to productivity increase both output and its natural level by the same proportion.

2.4 The Evolution of Productivity Shocks and the Dynamic Stochastic Phillips Curve

In what follows, we shall assume that the productivity shock a follows a first order autoregressive process of the form,

$$a_t = \eta_A a_{t-1} + \varepsilon_t^A \tag{27}$$

where ε^A is a white noise process, satisfying,

$$\varepsilon_t^A \sim N(0, \sigma_A^2)$$

Under this assumption, the dynamic stochastic Phillips curve takes the form,

$$u_t - \bar{u} = \lambda_1(u_{t-1} - \bar{u}) - \frac{1}{\alpha}(\pi_t - E_{t-1}\pi_t + \varepsilon_t^A) \tag{28}$$

Only unanticipated inflation and unanticipated shocks to productivity can affect deviations of the unemployment rate from its natural rate in this model. In the absence of shocks to inflation and productivity, the unemployment rate gradually converges to its natural rate, and, from (26), so does real output.

3 Optimal Monetary Policy and Inflation under Unemployment Persistence

We next turn to the determination of inflation. We assume that inflation is determined by monetary policy, after the realization of current shocks to productivity. Thus, we assume that the central bank has an informational advantage over wage setters in the determination of monetary policy. Monetary policy, and thus inflation, is chosen after nominal wages have been set, and after the central bank has observed the current state of the economy.

3.1 Optimal Time Consistent Contingent Inflation Policy

We shall assume that the central bank, acting as a government agency, uses its policy instruments, i.e either the money supply or nominal interest rates, in order to select a path for inflation that minimizes an inter-temporal quadratic loss function, that measures the welfare cost of inflation and unemployment. This loss function depends on deviations of inflation from a fixed target π^*, and deviations of unemployment from its natural rate. Thus, the central bank chooses inflation in order to minimize,[6]

$$\Lambda_t = E_t \sum\nolimits_{s=0}^{\infty} \beta^s \left(\frac{1}{2}(\pi_{t+s} - \pi^*)^2 + \frac{\zeta}{2}(u_{t+s} - \bar{u})^2 \right) \tag{29}$$

subject to the dynamic stochastic expectational Phillips curve (28). β is the discount factor, $\beta = 1/(1+\rho)$, where ρ is the pure rate of time preference, and ζ is the relative weight attached by the central bank to deviations of unemployment from its natural rate, relative to deviations of inflation from target.[7]

[6]We short circuit the demand side of the model, by assuming that the central bank can use either the money supply, or, more plausibly, nominal interest rates to achieve its inflation target. In Alogoskoufis (2016) we have analyzed a full dynamic stochastic general equilibrium version of the model, which includes a fully developed demand side, in order to study the properties of Taylor (1993) nominal interest rate rules, and compare such rules with optimal monetary policy.

[7]In accordance with the conventions of the literature on monetary policy, e.g Barro and Gordon (1983), Rogoff (1985), we treat (29) as a measure of the welfare costs of inflation and unemployment. However, we assume here that the central bank does not seek to systematically reduce unemployment below its natural rate. Thus, we abstract

We term the policy that results from the minimization of (29) subject to (28), as *contingent*, because the central banks choice of inflation will depend on the current state of the economy, summarized in the deviations of the current unemployment rate from the natural rate.

Note that under this policy, there is a clash between the objectives of the monetary authorities and the objectives of wage setting insiders regarding unemployment. The central bank seeks to minimize deviations of unemployment from its natural rate, whereas wage setters seek to minimize deviations of unemployment from a weighted average of the natural rate and past unemployment. This clash is what accounts for our main results regarding the persistence of inflation.

From the first order conditions for a minimum of (29) subject to (28), we get,

$$\pi_t = \pi^* + \frac{\zeta}{\alpha}\left(u_t - \bar{u}\right) + \frac{\zeta\beta\lambda_1}{\alpha}E_t\left(u_{t+1} - \bar{u}\right) \tag{30}$$

Using (28) to substitute for current and expected future deviations of the unemployment rate from its natural rate, after some rearrangement, we get,

$$\pi_t = \lambda_1\pi_{t-1} + (1-\lambda_1)\pi^* - \frac{\zeta(1+\beta\lambda_1^2)}{\alpha^2}\left(\pi_t - E_{t-1}\pi_t + \varepsilon_t^A\right) \tag{31}$$

The rational expectations solution of (31) is given by,

$$\pi_t = \lambda_1\pi_{t-1} + (1-\lambda_1)\pi^* - \frac{\zeta(1+\beta\lambda_1^2)}{\alpha^2 + \zeta(1+\beta\lambda_1^2)}\varepsilon_t^A \tag{32}$$

From (32), deviations of the ?optimal?, time consistent, contingent inflation rate from the inflation target π^* display the same degree of persistence, as the persistence of deviations of unemployment from its natural rate. The reason is that the central bank allows inflation to fluctuate in order to minimize deviations of unemployment from its natural rate. Since these deviations in unemployment display persistence, deviations of inflation from target will also display persistence under the optimal contingent policy.[8]

from the systematic inflation bias that would result in the case in which the central bank also sought to use inflation in order to reduce unemployment below its natural rate, as in Kydland and Prescott (1977) and Barro and Gordon (1983).

[8] Note from (32) that if deviations of unemployment from its natural rate did not persist, i.e in the case $\lambda_1 = 0$, the optimal contingent monetary policy rule would not result in persistent deviations of inflation from target. There would be deviations of inflation from

It is worth noting that the persistence of inflation under the optimal time consistent contingent monetary policy does not affect the persistence of unemployment. The reason is that wage setters can anticipate the persistent part of the inflation process, incorporate it in their expectations, and neutralize the effects of persistent inflation on unemployment. Thus, the only element of monetary policy that matters for unemployment is the unanticipated part, which is a function of the current productivity shock.

Note from (32) that anticipated inflation is given by,

$$E_{t-1}\pi_t = \lambda_1 \pi_{t-1} + (1-\lambda_1)\pi^* \tag{33}$$

Thus, from (32) and (33), unanticipated inflation is given by,

$$\pi_t - E_{t-1}\pi_t = -\frac{\zeta(1+\beta\lambda_1^2)}{\alpha^2 + \zeta(1+\beta\lambda_1^2)}\varepsilon_t^A \tag{34}$$

Substituting (34) in the dynamic expectational Phillips curve (28), we get,

$$u_t = \lambda_1 u_{t-1} + (1-\lambda_1)\,\bar{u} - \frac{\alpha}{\alpha^2 + \zeta(1+\beta\lambda_1^2)}\varepsilon_t^A \tag{35}$$

Optimal contingent monetary policy results in persistent inflation, but it is only the unanticipated part of inflation that helps mitigate the impact of productivity shocks on unemployment. The anticipated persistent part of inflation cannot affect unemployment, as it is neutralized by the adjustment of the expectations of the wage setting insiders. The resulting equilibrium is *time consistent*, as neither central banks nor insiders have any incentive to deviate from the equilibrium.[9]

π^* only in response to unanticipated shocks to productivity.

[9] In Alogoskoufis (2016) we demonstrate that the same results follow in the context of a full dynamic stochastic general equilibrium model with periodic wage contracts determined by labor market insiders, if the central bank follows a Taylor (1993, 1999) rule. Adjusting the central bank policy interest rate in response to deviations of inflation from target and deviations of unemployment from its natural rate, results in persistent deviations of inflation from the central bank?s target. The degree of persistence of such deviations is equal to the degree of persistence of deviations of unemployment from its natural rate. Thus, it is sufficient to assume a central bank that follows a Taylor rule for the results of the present paper to apply. See also Clarida, Gali and Gertler (1999) and Woodford (2003) on the properties of the Taylor rule. There is no need to assume that the central bank necessarily follows the optimal contingent policy for the results of this paper. It suffices to assume that the central bank follows a contingent policy rule such as a Taylor rule.

Under the optimal contingent policy, the variances of inflation and unemployment are given by,

$$Var(\pi_t) = E_t(\pi_t - \pi^*)^2 = \frac{1}{1-\lambda_1{}^2}\frac{\zeta^2(1+\beta\lambda_1^2)^2}{(\alpha^2+\zeta(1+\beta\lambda_1^2))^2}\sigma_A^2 \tag{36}$$

$$Var(u_t) = E_t(u_t - \bar{u})^2 = \frac{1}{1-\lambda_1{}^2}\frac{\alpha^2}{(\alpha^2+\zeta(1+\beta\lambda_1^2))^2}\sigma_A^2 \tag{37}$$

where σ_A^2 is the variance of the innovation in productivity.

From (29), the expected intertemporal welfare loss under the optimal time consistent contingent monetary policy rule is thus given by,

$$\Lambda_t^C = \frac{1}{2}\frac{1+\rho}{\rho}\frac{\zeta}{1-\lambda_1{}^2}\left(\frac{\alpha^2+\zeta(1+\beta\lambda_1^2)^2}{(\alpha^2+\zeta(1+\beta\lambda_1^2))^2}\right)\sigma_A^2 \tag{38}$$

where superscript C denotes the *contingent* time consistent inflation policy.

The first question that arises is whether the central bank can do better than the optimal contingent policy by following a non-contingent policy rule. Is it possible that the central bank can do better than the ?optimal? contingent policy by following a policy of full commitment to its inflation target, without being concerned about deviations of unemployment from its natural rate?

3.2 A Non contingent Policy of Full Commitment to the Inflation Target

In response to the credibility problems arising in the context of the natural rate models of Kydland and Prescott (1977) and Barro and Gordon (1982), Rogoff (1985) has suggested that the constitution of the central bank could be such, that instead of the central bank seeking to minimize a social loss function such as (29), the central bank could be instructed to pre-commit to a different policy rule, tilted towards inflation.

One such solution would be to appoint a central banker whose only objective is inflation. In the context of our model this would result in a non contingent policy of full commitment to the inflation target π^*.

In the case of full commitment to the inflation target, the central bank?s ζ would be zero, and its objective would be to minimize,

$$E_t \sum\nolimits_{s=0}^{\infty} \beta^s \left(\frac{1}{2} (\pi_{t+s} - \pi^*)^2 \right) \tag{39}$$

The policy that minimizes (39) implies that,

$$\pi_t = \pi^* \ \forall \ t \tag{40}$$

Clearly this policy is non contingent, as inflation is constant, and does not respond to deviations of unemployment from its natural rate.

Under this policy, unemployment would evolve according to,

$$u_t = (1 - \lambda_1) \bar{u} + \lambda_1 u_{t-1} - \frac{1}{\alpha} \varepsilon_t^A \tag{41}$$

as there would be no unanticipated inflation to mitigate the effects of productivity shocks on unemployment. Under full commitment to the inflation target monetary policy plays no role in the stabilization of unemployment around its natural rate. This is a policy rule of full credibility but no flexibility.

Under this policy rule, the variance of inflation would be equal to zero, and the variance of unemployment around its natural rate would be given by,

$$Var(u_t) = E_t (u_t - \bar{u})^2 = \frac{1}{(1 - {\lambda_1}^2) \alpha^2} \sigma_A^2 \tag{42}$$

The expected intertemporal social loss under the non contingent policy, assuming that society also cares about deviations of unemployment from its natural rate as in (29), would be given by,

$$\Lambda_t^{NC} = \frac{1}{2} \frac{1 + \rho}{\rho} \frac{\zeta}{(1 - {\lambda_1}^2) \alpha^2} \sigma_A^2 \tag{43}$$

where superscript NC denotes the *non contingent* inflation policy.

The expected loss would be higher under the non contingent policy than under the contingent policy, if,

$$\frac{1}{\alpha^2} > \left(\frac{\alpha^2 + \zeta (1 + \beta \lambda_1^2)^2}{(\alpha^2 + \zeta (1 + \beta \lambda_1^2))^2} \right) \tag{44}$$

For (44) to be satisfied, a necessary and sufficient condition is that,

$$\zeta^2(1+\beta\lambda_1^2)^2 + \alpha^2\zeta(1+\beta\lambda_1^2)(1-\beta\lambda_1^2) > 0 \tag{45}$$

This condition is always met for a positive ζ, since the discount factor is less than one ($\beta < 1$).Thus, for a positive relative weight on deviations of unemployment from its natural rate in the social welfare function , the non-contingent policy results in higher social losses than the optimal contingent policy.

Despite the persistence of inflation under the optimal contingent policy, and thus the higher variance of inflation, the contingent policy always dominates in this dynamic stochastic model, over the non contingent policy of full commitment to the inflation target.

Whereas the non contingent full commitment policy results in inflation always being equal to the central bank's target, this policy does not react at all to deviations of unemployment from its natural rate. As a result, the social welfare losses from fluctuations in unemployment are at their maximum, and social welfare is not maximized overall.

3.3 Inflation and Unemployment in the Presence of Non Systematic Monetary Policy Errors

Our results so far have been derived under the assumption that there are no errors in the implementation of the monetary policy rule. The results can be generalized for the case where monetary policy is characterized by a non systematic error, i.e a nominal shock. Such errors may arise because of imperfect information about current developments in unemployment, errors in the transmission of monetary policy or simply because of the imperfect implementation of monetary policy.

In this case the optimal inflation policy rule (30) under discretion would be transformed to,

$$\pi_t = \pi^* + \frac{\zeta}{\alpha}(u_t - \bar{u}) + \frac{\zeta\beta\lambda_1}{\alpha}E_t(u_{t+1} - \bar{u}) + \varepsilon_t^M \tag{46}$$

where ε^M is a white noise shock to monetary policy, satisfying,

$$\varepsilon_t^M \sim N(0, \sigma_M^2)$$

Using the dynamic Phillips curve (28) to substitute for the unemployment terms in (46), and solving for inflation under the assumption of rational expectations, we get that under the optimal contingent monetary policy, inflation follows,

$$\pi_t = (1-\lambda_1)\pi^* + \lambda_1 \pi_{t-1} - \frac{\zeta(1+\beta\lambda_1^2)}{\alpha^2+\zeta(1+\beta\lambda_1^2)}\varepsilon_t^A + \frac{\alpha^2}{\alpha^2+\zeta(1+\beta\lambda_1^2)}\left(\varepsilon_t^M - \lambda_1 \varepsilon_{t-1}^M\right) \tag{47}$$

As in the case of (32), the persistence of deviations of inflation from the target of the central bank is equal to the persistence of deviations of unemployment from its natural rate.

From (47) it follows that unanticipated inflation is given by,

$$\pi_t - E_{t-1}\pi_t = -\frac{\zeta(1+\beta\lambda_1^2)}{\alpha^2+\zeta(1+\beta\lambda_1^2)}\varepsilon_t^A + \frac{\alpha^2}{\alpha^2+\zeta(1+\beta\lambda_1^2)}\varepsilon_t^M \tag{48}$$

From (48) unanticipated inflation also depends on the current monetary policy error or shock.

Substituting (48) in the dynamic expectational Phillips curve (28), we get,

$$u_t = \lambda_1 u_{t-1} + (1-\lambda_1)\,\bar{u} - \frac{\alpha}{\alpha^2+\zeta(1+\beta\lambda_1^2)}\left(\varepsilon_t^A + \varepsilon_t^M\right) \tag{49}$$

Under the optimal contingent monetary policy deviations of unemployment from its natural rate are driven by both productivity and monetary policy shocks, and they display the same degree of persistence as inflation.

In the presence of non-systematic monetary policy errors, the variances of inflation and unemployment under the contingent monetary policy rule are given by,

$$Var(\pi_t) = \frac{1}{1-{\lambda_1}^2}\left(\left(\frac{\zeta^2(1+\beta\lambda_1^2)}{(\alpha^2+\zeta(1+\beta\lambda_1^2))}\right)^2\sigma_A^2 + \left(\frac{\alpha^2}{(\alpha^2+\zeta(1+\beta\lambda_1^2))}\right)^2\left(1-{\lambda_1}^2\right)\sigma_M^2\right)$$

$$Var(u_t) = \frac{1}{1-{\lambda_1}^2}\left(\frac{\alpha}{(\alpha^2+\zeta(1+\beta\lambda_1^2))}\right)^2\left(\sigma_A^2+\sigma_M^2\right)$$

Again, it is only the unanticipated part of inflation that helps mitigate the impact of productivity and monetary policy shocks on unemployment. The anticipated persistent part of inflation cannot affect unemployment, as it is neutralized by the adjustment of the expectations of wage setting insiders.

Under the non contingent policy, inflation and unemployment follow,

$$\pi_t = \pi^* + \varepsilon_t^M \tag{50}$$

$$u_t = (1 - \lambda_1)\,\bar{u} + \lambda_1 u_{t-1} - \frac{1}{\alpha}\left(\varepsilon_t^A + \varepsilon_t^M\right) \tag{51}$$

In this case, the variances of inflation and unemployment are given by,

$$Var(\pi_t) = \sigma_M^2$$

$$Var(u_t) = \frac{1}{1 - {\lambda_1}^2}\frac{1}{\alpha^2}\left(\sigma_A^2 + \sigma_M^2\right)$$

It is straightforward to demonstrate, by using these variances, that even in the presence of monetary policy errors (nominal shocks), the optimal contingent policy dominates the non-contingent policy of full commitment to the inflation target, as it implies a lower expected social welfare cost of inflation and unemployment, if the expected social welfare cost is measured by (29).

Thus, even in the presence of monetary policy errors (nominal shocks), the theoretical predictions of this model continue to hold. They suggest that, if a central bank follows the optimal, time consistent, contingent policy rule, a rule that depends on deviations of unemployment from its natural rate, deviations of inflation from target should display the same degree of persistence as unemployment deviations from the natural rate. They also suggest that a contingent policy dominates a non-contingent policy.

Thus, on the basis of our analysis, the persistence of inflation in economies where deviations of unemployment from its natural rate display persistence, can be explained as the side effect of the clash between central banks and labor market insiders, when central banks follow time consistent, contingent monetary policy rules.

4 Addressing Inflation Persistence through Pre-Commitment to a Time Inconsistent Contingent Rule

The final question we want to address is whether there exist time inconsistent contingent rules with better stabilization properties than the time consistent contingent rule.

Note that the time consistent contingent rule results in inflation persistence because wage setters anticipate the incentives of central banks to respond to persistent deviations of unemployment from its natural rate, and adjust their inflationary expectations accordingly.

If central banks pre-committed to a time inconsistent contingent monetary policy rule, that did not result in inflation persistence, and stuck to it, expectations of wage setters would shift to an equilibrium without inflation persistence. Such a rule could be sustained either through a pre-commitment technology, such as an amendment of the statutes of the central bank, or through reputational mechanisms, in a similar fashion as the non contingent policy rule. Such mechanisms have been studied extensively in related models, since Rogoff (1985). Hence, our analysis will be brief.[10]

Assume that instead of the optimal time consistent inflation rule (30), the central bank pre-committed to a policy rule of the form,

$$\pi_t = \pi^* + \psi \left(u_t - \left(1 - \lambda_1\right) \bar{u} - \lambda_1 u_{t-1} \right) \tag{52}$$

$\psi > 0$ is a policy parameter that measures the response of inflation to innovations in unemployment rather than deviations of unemployment from its natural rate. (52) implies that deviations of inflation from the target π^* depend on deviations of unemployment from its one period ahead forecast at the end of period $t-1$, which are obviously non persistent.

If this rule was credible, then, ex ante expected inflation would always be equal to π^*, i.e,

$$E_{t-1}\pi_t = \pi * \tag{53}$$

From the policy rule (52), from (53), and and from the dynamic stochastic expectations augmented Phillips curve (28), unemployment would then follow,

[10]See Lockwood and Philippopoulos (1994), Walsh (1995), Hehrendorf and Lockwood (1997), Lockwood (1997), Svensson (1997), Lockwood et al (1998), who have studied various forms of reputational equilibria and pre-commitment mechanisms such as contracts for central bankers. This section was developed in response to the comments of the editor, Francesco Caselli and an anonymous referee. For simplicity we concentrate on the case where there are no errors in the implementation of monetary policy, i.e. no nominal shocks. It is straightforward to extend the analysis to the case of nominal shocks.

$$u_t - \bar{u} = \lambda_1(u_{t-1} - \bar{u}) - \frac{1}{\alpha}(\pi_t - E_{t-1}\pi_t + \varepsilon_t^A) = \lambda_1(u_{t-1} - \bar{u}) - \frac{1}{\alpha + \psi}\varepsilon_t^A \quad (54)$$

Thus, to the extent that the policy response parameter ψ is positive, the effects of productivity shocks on unemployment would be smaller that under the non-contingent policy rule (40), since under the contingent policy rule (52) monetary policy reacts to innovations in unemployment and hence to innovations in productivity.

Substituting (54) to the policy rule (52), inflation would be determined by,

$$\pi_t = \pi^* - \frac{\psi}{\psi + \alpha}\varepsilon_t^A \quad (55)$$

Equilibrium inflation would thus display no persistence if the central bank pre-committed to the policy rule (52). However, inflation responds to productivity shocks, and is no longer constant as in the case of the non contingent policy rule (40). There are stabilizing deviations of inflation from the target, but these are non persistent.

How does this reputational time inconsistent contingent policy compare to the optimal time consistent contingent policy (30)? This depends on the choice of the policy parameter ψ.

The variances of inflation and unemployment under the reputational equilibrium based on the policy rule (52) are given by,

$$Var(\pi_t) = \left(\frac{\psi}{\psi + \alpha}\right)^2 \sigma_A^2$$

$$Var(u_t) = \frac{1}{1 - \lambda_1{}^2}\left(\frac{1}{\psi + \alpha}\right)^2 \sigma_A^2$$

A higher ψ increases the variance of inflation and reduces the variance of deviations of unemployment from its natural rate. Thus, by appropriately choosing ψ the central bank can choose the combination between the variances of inflation and unemployment in the reputational equilibrium that minimizes social welfare losses.

The variance of inflation will be lower than in the time consistent equilibrium, if,

$$\frac{\psi}{\psi+\alpha} < \frac{1}{\sqrt{1-\lambda_1{}^2}} \frac{\zeta(1+\beta\lambda_1^2)^2}{\alpha^2+\zeta(1+\beta\lambda_1^2)}$$

The variance of unemployment will be lower than in the time consistent equilibrium if,

$$\frac{1}{\psi+\alpha} < \frac{\alpha}{\alpha^2+\zeta(1+\beta\lambda_1^2)}$$

The significance of a reputational equilibrium around a policy rule such as (52) is that inflation no longer displays persistence, and that the welfare losses from fluctuations in inflation and unemployment can be reduced below the welfare losses associated with the time consistent optimal contingent policy rule (30).

The expected welfare losses under the reputational equilibrium, on the basis of the policy rule (52) are given by,

$$\Lambda_t^R = \frac{1}{2}\frac{1+\rho}{\rho}\frac{1}{(\psi+\alpha)^2}\left(\psi^2 + \frac{\zeta}{1-\lambda_1{}^2}\right)\sigma_A^2 \tag{56}$$

where superscript R denotes the reputational equilibrium.

The expected social welfare losses under the reputational equilibrium are minimized with respect to ψ when,

$$\psi = \frac{\zeta}{\alpha(1-\lambda_1{}^2)} \tag{57}$$

The best response of inflation to unemployment in a reputational equilibrium based on (52) depends positively on ζ, the relative weight of unemployment relative to inflation in the social welfare function, $1/\alpha$, the responsiveness of unemployment to unanticipated inflation and λ_1, the persistence of unemployment.

By comparing the expected welfare losses between the time consistent equilibrium in (38), and the time inconsistent reputational equilibrium in (56), one can easily show that for a sufficiently high degree of unemployment persistence, the reputational time inconsistent equilibrium, based on the appropriate choice of ψ, can result in lower welfare losses than the time consistent equilibrium.[11]

[11] For example, if $\lambda_1 = 0.5$, as is the average estimate for the G-7 economies, for $\zeta = 1$,

Hence, on the basis of the analysis in this paper, there is scope for welfare gains by reducing the persistence of inflation, which is in any case not only unnecessary but also counterproductive in the context of our model. This requires pre-commitment to a time inconsistent contingent policy rule, according to which central banks target their responses to unanticipated changes (innovations) in unemployment rates and not deviations of unemployment rates from their presumed natural rates. Under such a rule the persistence of inflation would disappear, and there could be potentially significant welfare gains.[12]

5 Conclusions

This paper has analyzed the implications of monetary policy rules for the behavior of inflation in a dynamic stochastic natural rate model, characterized by endogenous unemployment persistence.

We first presented evidence for the main industrial economies, the G-7, which suggests that the persistence of inflation is of the same order of magnitude as the persistence of deviations of unemployment from its natural rate.

We then set out to explain this fact, by putting forward a small dynamic stochastic macro model, in which unemployment and inflation persistence are determined by the wage setting behavior of labor market insiders and the monetary policies of central banks using time consistent contingent monetary policy rules.

The main distinguishing characteristic of the model put forward in this paper is a dynamic stochastic insider outsider version of the Phillips curve. This for the persistence of unemployment following nominal and real shocks.

We derived the optimal time consistent contingent monetary policy rule, by assuming a central bank that minimizes an inter-temporal quadratic loss function depending on deviations of inflation from an exogenous inflation target and unemployment from its natural rate.

$\alpha = 0.67$ and $\beta = 0.99$, the expected welfare losses under a reputational equilibrium without inflation persistence are 20% lower than in the corresponding time consistent equilibrium with inflation persistence.

[12]As pointed out by a referee, the same argument can be made about a time inconsistent contingent policy rule that targets deviations from the natural rate, as long as the parameters of the rule differ from the time consistent optimal policy rule. However, in such a case inflation would continue to display persistence.

We demonstrated that because of the persistence of deviations of unemployment from its natural rate, deviations of the inflation rate from target inflation will also display persistence, which will be equal to the persistence of unemployment. The persistence of inflation arises because of the clash in the objectives of central bankers and labour market insiders.

We next examined non-contingent monetary policy rules, under full commitment to an inflation target. In such a case, there is no inflation persistence, as the central bank achieves its inflation target in every period. However, under such a rule, monetary policy cannot stabilize fluctuations in unemployment caused by unanticipated productivity or monetary policy shocks.

We demonstrated that, in the the presence of unanticipated shocks, the optimal time consistent contingent rule dominates the non contingent rule of full commitment to the inflation target.

We also demonstrated that the problem of the persistence of inflation could be solved in a welfare improving way, if central banks pre-committed to time inconsistent monetary policy rules that targeted unanticipated changes in unemployment rates, and not deviations of unemployment from their presumed natural rates.

Out main conclusion from the analysis of this paper is that, in the presence of unemployment persistence, inflation persistence of the same magnitude can be explained as the outcome of a clash between central bankers and labour market insiders, when the latter try to stabilize both inflation and deviations of unemployment around its natural rate. The main policy prescription that springs from this analysis is that the persistence of inflation can be addressed in a welfare improving way if central banks targeted unanticipated changes in unemployment rather than deviations from the natural rate.

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Table 1
The Persistence of Unemployment in the G7
Annual Data, 1952-2014

Dependent Variable: $(u\text{-}\bar{u})_t$

	USA	Japan	Germany	France	Italy	UK	Canada
$(u\text{-}\bar{u})_{t-1}$	0.711	0.925	1.134	0.924	0.791	1.122	0.846
	(0.118)	(0.117)	(0.098)	(0.114)	(0.127)	(0.107)	(0.116)
$(u\text{-}\bar{u})_{t-2}$	-0.399	-0.425	-0.650	-0.455	-0.195	-0.637	-0.402
	(0.118)	(0.118)	(0.098)	(0.115)	(0.127)	(0.107)	(0.115)
Persistence	0.311	0.500	0.484	0.468	0.596	0.485	0.444
	(0.120)	(0.099)	(0.078)	(0.098)	(0.107)	(0.084)	(0.104)
R^2	0.377	0.523	0.694	0.529	0.451	0.653	0.476
s	0.0084	0.0022	0.0044	0.0038	0.0063	0.0055	0.0073
DW	2.136	1.925	2.038	2.040	2.057	1.837	2.136
ADF	-5.620	-4.085	-5.230	-4.624	-3.759	-4.591	-5.274

Note: $\bar{u}$ is approximated by a Hodrick-Prescott Filter. A constant is included but is not statistically significant.

Table 2
The Persistence of Inflation in the G7
Annual Data, 1952-2014

Dependent Variable: π_t

	USA	Japan	Germany	France	Italy	UK	Canada
Constant	0.015	0.004	0.012	0.018	0.012	0.020	0.012
	(0.004)	(0.005)	(0.002)	(0.005)	(0.004)	(0.005)	(0.003)
1972-1982	0.035	0.040	0.016	0.051	0.058	0.060	0.042
	(0.007)	(0.014)	(0.004)	(0.011)	(0.010)	(0.014)	(0.006)
1952-1971		0.020					
		(0.009)					
π_{t-1}	0.564	0.557	0.907	0.358	0.458	0.635	0.477
	(0.108)	(0.131)	(0.106)	(0.108)	(0.096)	(0.135)	(0.094)
π_{t-2}	-0.174	-0.095	-0.459	0.016	0.137	-0.240	-0.042
	(0.097)	(0.116)	(0.087)	(0.102)	(0.084)	0.116)	(0.083)
Persistence	0.390	0.462	0.448	0.374	0.595	0.395	0.435
	(0.107)	(0.132)	(0.092)	(0.104)	(0.074)	(0.121)	(0.073)
π^*	0.025	0.007	0.021	0.029	0.029	0.034	0.022
	(0.003)	(0.009)	(0.002)	(0.006)	(0.008)	(0.005)	(0.003)
π^* (1972-82)	0.083	0.082	0.050	0.110	0.172	0.133	0.097
	(0.007)	(0.015)	(0.005)	(0.013)	(0.017)	(0.012)	(0.007)
R^2	0.729	0.627	0.771	0.600	0.850	0.770	0.839
s	0.0148	0.0262	0.0087	0.0263	0.0213	0.0235	0.0125
DW	1.522	1.890	2.069	2.340	1.755	2.136	1.390
ADF	-5.706	-4.066	-6.018	-6.029	-5.481	-5.009	-7.735

Note: Inflation based on the Consumer Price Index. Estimates for Japan, Germany and the UK, 1953-2014.

Data Appendix

The data set used in this study is as follows:

u is the civilian unemployment rate, and π is the rate of change of the Consumer Price Index.

The data set has been compiled from the *AMECO Data Base* of the European Union, for the period 1960-2014, and from the OECD data bases and the IMF *International Financial Statistics* for the period 1948-1959. The data set used is available upon request.