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**The Enigmatic Long-Run Relation Between
Inflation and Unemployment**

by

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Abstract. A puzzling result concerning the recent evolution of the US economy regards the joint dynamics of inflation and unemployment in the second part of the 1990s, when a simultaneous decrease of both variables was experienced. In this paper we build upon a line of research whose explanation attributes an important role to productivity growth fluctuations. The aim of the paper is twofold. First, we provide an estimation of productivity growth shock effects in the context of the dynamic Phillips relation and show that these effects hold for the whole postwar period. Moreover, the role played by these shocks is, as expected, much stronger in more specific historical episodes. Second, we investigate the possible presence of a stochastic trend in productivity growth rate and relate the results to some recent studies which cast doubt on the existence of a long-run vertical Phillips curve.

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1. Introduction

The presence of low-frequency, persistent comovements between inflation and unemployment appears, *prima facie*, as in contrast with traditional natural-rate and NAIRU (non-accelerating inflation rate of unemployment) models, since these models predict long-run independence between the two variables.

Indeed, in recent years, some papers have appeared in the literature which cast doubt on the traditional natural rate of unemployment model. The stimulus originated from the observation that in the second half of the 1990s inflation and unemployment moved in the same direction in the United States, for both variables witnessed a significant reduction from the average level of the previous decade. Moreover, this represented a sort of reverse story with respect to the 1970s that were instead characterized by a simultaneous increase of inflation and unemployment.

An interpretation of the long-run positive relation between inflation and unemployment is offered by a strand of research which gives a dominant role to supply shocks. More precisely, fluctuations in productivity growth might explain the fluctuations in the NAIRU since the slow adaptation of workers' claim to

productivity growth would prevent a rapid alignment between workers' claims and the feasible real wage. Grubb *et al.* (1982) proposed this analytical framework to explain the persistent slowdown of the 1970s.

Recently, Ball and Mankiw (2002) attributed a prominent role to productivity growth fluctuations for the explanation of the enigmatic interaction between inflation and unemployment which characterized the second part of the 1990s in the US economy.

Note that this framework predicts the presence of persistent shocks affecting the dynamic process of productivity growth. Moreover, the existence of a close link between persistency in productivity growth and persistency both in inflation and unemployment is also predicted.

Yet, in our opinion, there are still some unsettled questions concerning this line of research that are worth investigating. In particular: (i) do shocks to productivity growth exert only a temporary effect on inflation and unemployment or, instead, do these effects also hold in medium and long run? (ii) A closely related question concerns the possibility that productivity growth contains a stochastic trend. Although there is an overwhelming evidence in support of stationarity of the series, we want to show that it remains at least an open question. Yet, once a unit root in the variable is detected, then the way is paved for the possibility of low-frequency effects of productivity growth shocks on both inflation and unemployment. We aim to show that, indeed, this could be a plausible representation for the US economy in the postwar period.

The paper is organized as follows. In section 2 we present the theoretical framework underlying the idea of a link among productivity growth, inflation and unemployment. Section 3 presents some estimates of a Phillips curve for the US in the postwar period which incorporates the potential effects exerted by discrepancies between current and expected productivity growth rate. The results show that these effects are significant for the postwar period, 1960-2004 and given the estimated coefficients we build an estimation for the NAIRU which takes into account productivity growth shocks. Moreover, and in line with the prediction of the analytical framework, when we analyze specific historical episodes, namely the periods 1970-1979 and 1995-2004, the role of productivity growth shocks becomes stronger. In section 4 we investigate the nature I(0) or, alternatively, I(1) of productivity growth. Although the majority of the studies on this subject find that an I(0) representation appears consistent with postwar data, we show, by also using recently developed unit roots test, that the I(1) assumption may not be rejected. In our view the importance of this analysis is related to some recent results (see *e.g.* Beyer and Farmer, 2003) which show the existence of a positive low-frequency relation between inflation and unemployment. We wonder if it is

possible that the common explanation for this equilibrium relationship lies in a unit root in shocks to productivity growth and thus, in section 5, we test for the possible presence of equilibrium long-run relations among the variables. Indeed, the existence of two cointegrating relations may be consistent with postwar US data and the results reveal two distinct equilibrium relationships which imply an inverse relation between, respectively, (i) productivity growth and unemployment, (ii) productivity growth and inflation. Section 6 concludes.

2. Theoretical Framework

The technology is represented by:

$$Y_t = a_t N_t \quad (1)$$

The rate of growth of labor productivity, $g_t = (a_t - a_{t-1})/a_{t-1}$ follows the process:

$$g_t = \vartheta(L)g_{t-1} + \eta_t \quad (2)$$

where L is the lag operator and η_t is an error term which captures unexpected changes in productivity growth. Notice that if $\vartheta(1) = 1$, then g_t is nonstationary and innovations have a permanent effect on the rate of growth of productivity.

Price dynamics is described by the usual specification:

$$\pi_t = \omega_t - g_t + \epsilon_t \quad (3)$$

Where the rate of change of price, π_t , depends on the rate of change of wages, ω_t , and is inversely related to the rate of change of productivity. The error term, ϵ_t , reflects unexpected changes from the supply side which can influence the price dynamics for given unit labour costs. An implication of equation (3) is that the price setters know the current rate of productivity growth.

Wage dynamics are described by the following relation:

$$\omega_t - \pi_t^e = \tau + g_t^e - \alpha U_t + \theta_t \quad (4)$$

Equation (4) is a wage-setting relation in which it is assumed that the real wage growth target is inversely related to the unemployment rate, U , and moves one for one with expected productivity growth, g_t^e . The constant term, τ , depends on institutional factors characterizing the labor market, while θ_t is an error term. In this context, g_t^e can also be interpreted as the target of real wage growth in the absence of cyclical unemployment.

By inserting equation (4) in price dynamics and eliminating ω_t we obtain the Phillips relation:

$$\pi_t = \tau + \pi_t^e - \alpha U_t - (g_t - g_t^e) + \rho_t \quad (5)$$

where $\rho_t = \epsilon_t + \theta_t$. Thus, productivity shocks may exert influence on inflation and unemployment in the presence of discrepancies between current productivity growth and real wage growth target. Let us consider the following specification for g_t^e :

$$g_t^e = \lambda g_t + (1 - \lambda) \vartheta(L) g_{t-1} \quad (6)$$

where $0 \leq \lambda \leq 1$. If λ is strictly less than one, then real wage growth target does not immediately adjust to productivity growth. The economic rationale for this situation rests on two possible explanations, not indeed mutually exclusive: (i) it requires time for workers to adjust expectations concerning the productivity growth since expectations are mainly driven by past levels of productivity growth. (ii) Workers have wage aspirations and thus they form an idea of what is a fair rate of wage growth. Moreover, this fair rate is fairly stable being principally linked to past wage increases, *i.e.* once again to past growth rates of productivity. The consequence is that in the presence of changes in the pace of productivity growth workers need time to adjust their aspirations to the new path of the economic system. This last is, for example, the interpretative line given in some papers such as Stiglitz (1997), and Ball and Moffitt (2002).

Notice that this last explanation relies on a particular form of real wage stickiness which is founded on a slow adapting behaviour of workers in relation to real wage growth target.

Instead, as far as explanation (i) is concerned, it is worth observing that even in the presence of perfect information by workers about the pace of productivity

growth, there could be a slow adaptation of real wage growth claims to the feasible real wage growth. All in all, if wage contracts are staggered over time only a fraction of them can contemporaneously respond to productivity growth changes. In this case, λ could depend on the fraction of contracts which is signed in the current period. This explanation would be more in the tradition of the researches pioneered by Fisher (1977) and Taylor (1980) which relies on nominal rigidities. In future extensions of the research it may be worth exploring the role of the staggering of wage contracts as a propagation mechanism for labor productivity growth shocks. Yet, it should be noted that if the staggering of wage contracts represents the main source of productivity growth effects on inflation and unemployment then persistent, low-frequency effects are unlikely to manifest.

By inserting equation (6) in the Phillips relation, we obtain:

$$\pi_t = \tau + \pi_t^e - \alpha U_t - (1 - \lambda)(g_t - \vartheta(L)g_{t-1}) + \rho_t \quad (7)$$

Let us consider the following two cases: (1) take $\lambda = 1$. In this situation we have the traditional (neoclassical) case in which productivity growth shocks have no effects on inflation and unemployment; (2) At the other extreme, if $\lambda = 0$, unexpected changes in productivity growth translate one for one into the inflation rate and produce also shift in the NAIRU. It is worth noticing that in empirical investigations concerning the Phillips curve, dynamic specifications are usually adopted which also include lagged terms of inflation and unemployment.

As far as inflation expectations are concerned, we make the widely used, adaptive behaviour assumption: $\pi_t^e = \pi_{t-1}$. Hence, in a context of stable inflation, we have the following expression for the NAIRU:

$$U_N = \frac{\tau}{\alpha} - \frac{1 - \lambda}{\alpha} (g_t - \vartheta(L)g_{t-1}) + \frac{1}{\alpha} \rho_t \quad (8)$$

Equation (8) can be rewritten as:

$$U_N = \frac{\tau}{\alpha} - \frac{1 - \lambda}{\alpha} \eta_t + \frac{1}{\alpha} \rho_t \quad (9)$$

The first term on the right hand side shows that long-run unemployment

depends on a constant term given by the ratio of the constant in the Phillips curve (and in the wage equation), τ , to the unemployment coefficient α . This constant term is mainly explained by institutional factors of the labor market. Indeed, long-run unemployment is also affected by price and wage shocks, expressed by the error term ρ_t , but if these shocks are stationary then the NAIRU, though not constant, fluctuates around its mean. Moreover, notice that equation (9) has another important implication: productivity growth shocks might influence the NAIRU in the presence of a positive value of λ . Moreover, and not less important, the shift in the NAIRU could be permanent whereas η_t follows a non-stationary process.

Grubb *et al.* (1982) were the first to point out the role of productivity growth in shaping the inflation-unemployment relation. In particular, they stressed the possibility that a slow adjustment of workers' claims to sudden changes in the rate of productivity growth could be seen as the key explanation of the simultaneous increase in unemployment and inflation which hit most industrialized countries in the 1970s.

In a recent paper Ball and Moffitt (2002) have used this scheme to investigate some features of the US Phillips curve in the 1990s. In particular, they explore the notion of wage aspiration and build a relation in which the aspiration real wage growth depends on past increases. Then, by assuming that the variable expressing the aspiration may differ from productivity growth, the authors leave room for the possibility that a productivity acceleration (deceleration) induces a favorable (unfavorable) shift in the relation between inflation and unemployment.

In the empirical part of the paper the authors show that the inflation-unemployment trade-off is influenced by fluctuations in productivity growth rate. Yet, their specification excludes the possibility that shocks to productivity growth may produce a permanent shift in the Phillips relation and thus the model preserves the existence of a vertical long-run Phillips curve. Nevertheless, a series of recent papers concerning the US economy has challenged this view by showing that an equilibrium long-run relation between inflation and unemployment may not be rejected in postwar data (see *e.g.* Ireland 1999, Beyer and Farmer 2003 and Ribba 2005). Notice that the expression we derived for the NAIRU (cf. equation 9) predicts, instead, the possibility of permanent effects on long-run equilibrium unemployment exerted by shocks affecting productivity growth. Given equation 9, these permanent effects would descend by the presence of a stochastic trend in the dynamic process of productivity growth.

3. Productivity Growth and the Phillips Relation in Postwar Data

In this section we empirically explore the role of productivity growth in the Phillips relation by considering quarterly US postwar data. In particular, we estimate an observable counterpart of equation (7). We consider the labor productivity in the business sector. As far as the measure of productivity growth is concerned, it is important to stress that the series contains a wide short-run variability and that, as a consequence, it would make little sense for workers to consider a target of real wage growth subject to such high-frequency instability. Thus, a smoother indicator is required and our first step consists in taking the annual rate of growth. As a second step we introduce a further smoothing of the series by choosing the following measure: $\bar{g}_t = \frac{\sum_{i=0}^3 g_{t-i}}{4}$. In other words, we take a four period average of annual labor productivity growth. The growth rate of prices is given by the annual rate of inflation measured by the consumer price index and unemployment is the civilian unemployment rate¹.

We start by estimating the following equation for the period 1960-2004:

$$\Delta\pi_t = \tau - \alpha U_t - \phi\eta_t + \delta\Delta\pi_{t-1} - \psi\Delta U_{t-1} \quad (10)$$

where $\phi = 1 - \lambda$ and $\eta_t = (\bar{g}_t - \vartheta(L)\bar{g}_{t-1})$. Thus, we want to evaluate the influence of productivity growth shocks in the context of a dynamic Phillips curve. The autoregressive dynamics of productivity growth was approximated by an AR(2) process with the inclusion of a constant term. The results are reported in table 1 and show an estimation of the coefficient ϕ which is significantly different from zero. Given the standard error, this implies an estimation for the coefficient λ which is strictly less than one. The sign is in line with the model prediction, implying that productivity growth shocks cause movements in the opposite direction of inflation. Hence, the first important conclusion we draw is that productivity growth has played an important role in shaping the interaction between inflation and unemployment in postwar US economy, since the results reveal that given an inverse relation between the growth of inflation and unemployment, an increase (decrease) in the rate of growth of labor productivity produces a favorable (unfavorable) shift in the relation.

¹ The series are taken from Fred at the St.Louis Web site. When the series have monthly frequency, a quarterly average is considered.

At a second stage we concentrate attention on more specific historical phases. For, if the analytical scheme has interpretative power then we expect to find a much stronger role for productivity growth shocks in those periods which were characterized by sudden changes, *i.e.* the productivity slowdown of the 1970s and the unexpected acceleration of the second part of the 1990s. Indeed, the results (see table 1) confirm this prediction since the size of coefficient ϕ increases, implying an estimated λ near one. Another interesting result concerns the very similar estimates of the coefficient ϕ for the two sample periods.

insert table 1 about here

Note that the conventional measure for the NAIRU implied by the estimated Phillips relation for the whole sample period, 1960-2004, is 6 percent². Nevertheless, an alternative estimation of the NAIRU is implied by equation (9) and it allows the effects exerted by productivity growth to be considered. Figure 1 reports this estimated measure for the postwar period. The evolution of the estimated NAIRU shows that peaks in long-run unemployment were achieved in the 1970s and that a declining shape seemed to characterize the 1990s. Hence, the qualitative pattern appears quite satisfying. Yet the estimated series has, in our opinion, a too limited range, varying from a minimum of 5.5 percent to a maximum of 6.5 percent. In particular, given the size of adverse supply shocks which affected the economic system in the 1970s, we expected to find an even higher level of long-run unemployment.

There is another important feature of this measure of the NAIRU which is worth stressing: since we are estimating a sort of low-frequency indicator of unemployment which is influenced by shocks affecting a smoothed measure of productivity growth, then the NAIRU, though variable, should be largely insensitive to business-cycle fluctuations. This prediction is confirmed since, for example, during the recession of 1990-1991 the NAIRU is comprised between 6 and 6.1 percent (in the first quarter of 1991). As far as more recent episodes are concerned, we note that in the second quarter of 2000 (around the peak of the long expansion of the second half of the 1970s) the NAIRU was 5.7 percent and in the second quarter of 2002 its measure was 5.8 percent.

² This result is obtained by the ratio of the constant term, τ , to the unemployment coefficient, α . The NAIRU, in this context, would be the long-run rate of unemployment associated with expectations concerning inflation which are correct and absent productivity shocks and other supply shocks. Yet, we re-estimated the Phillips relation by restricting to zero the coefficient, ϕ . We found that the implied, constant NAIRU remains substantially unchanged.

insert figure 1 about here

Ball and Moffitt (2002) estimate a Phillips curve for the period 1962-1995. They do not provide an estimation for specific sub-samples periods and instead use their model to produce a forecast of inflation over the five-year period 1996-2000. The authors show that the inclusion of productivity growth and wage aspirations allows the overprediction of inflation, generated by traditional Phillips curves, to be corrected. Staiger *et al.* (2002) maintain that the price puzzles of the 1990s disappear when one takes into account the univariate trends of unemployment and productivity growth. Their estimations seem to suggest that the relationship between the two long-run components could be an important factor underlying movements of inflation and unemployment over the 1990s.

Indeed, an exploration in the properties of the trend component of productivity growth rate is made in the next section of this paper, and since a unit root is detected, we then try to shed light on the possible presence of long-run equilibrium relations in the variables.

4. A Unit Root in Productivity Growth Rate?

The unit root properties of inflation and unemployment have been extensively investigated (for some recent results see *e.g.* Beyer and Farmer, 2003 and Staiger *et al.* 2002) and their representation as I(1) processes appears as not incoherent with US postwar data. Some of these studies have also investigated the low-frequency properties of productivity growth rate. The results show that although the dynamic process of productivity growth exhibits a considerable degree of persistence, the hypothesis of a unit root in the variable is generally rejected. Nevertheless, as pointed out by Staiger *et al.* (2002), some peculiarity of productivity growth might pose some difficulties in detecting the presence of a unit root³. Moreover, it is widely recognized that standard unit root tests suffer from low power and size distortions (see *e.g.* Ng and Perron, 2001).

In this section we want to reconsider the question concerning the low frequency properties of productivity growth by also using some recently developed unit root tests (see Elliott *et al.*, 1996 and Ng and Perron, 2001) which are more powerful than traditional tests.

When we apply the augmented Dickey Fuller (ADF) test to our selected

³ The authors observe that it could be difficult to formally detect the presence of a unit root in the presence of a dominant variability of the cyclical component and of a small variance of the permanent component of productivity growth

measure of productivity growth, \bar{g}_t , for the period 1960-2004 we find that the hypothesis of a unit root cannot be rejected at the 5 per cent level (see table 2). Let us recall that the ADF test is based on the following test equation:

$$\Delta\bar{g}_t = \mu + a\bar{g}_{t-1} + b_1\Delta\bar{g}_{t-1} + \dots + b_p\Delta\bar{g}_{t-p} + v_t \quad (11)$$

where the null hypothesis, $a = 0$, of a unit root in the series \bar{g}_t is based on the t -ratio for a . In general, the ADF test regression could also include a linear time trend, depending on the specific properties of the series. Yet, a well known weakness of the ADF test consists in the arbitrary low power as against a sufficiently close alternative. Elliott *et al.* (1996) show that power gains can be obtained by adopting a procedure of locally GLS detrending of the series. The authors suggest the following test equation:

$$\Delta\bar{g}_t^d = a\bar{g}_{t-1}^d + b_1\Delta\bar{g}_{t-1}^d + \dots + b_p\Delta\bar{g}_{t-p}^d + v_t \quad (12)$$

where \bar{g}_t^d is the detrended productivity growth series. In general, given any series $\{x_t\}_{t=0}^T$, let us consider $(x_0^{\bar{\alpha}}, x_t^{\bar{\alpha}}) \equiv (x_0, (1-\bar{\alpha}L)x_t)$ for some selected $\bar{\alpha} = 1 + \bar{c}/T$. The detrended series is given by:

$$\bar{g}_t^d = \bar{g}_t - \hat{\xi}' z_t \quad (13)$$

where $\hat{\xi}$ minimizes $S(\bar{\alpha}, \xi) = (\bar{g}^{\bar{\alpha}} - \xi' z_t^{\bar{\alpha}})'(\bar{g}^{\bar{\alpha}} - \xi' z_t^{\bar{\alpha}})$. The value suggested for \bar{c} when the presence of a linear time trend is excluded is -7.0 .

Just as in the ADF test, one has to evaluate the t -ratio for testing $a = 0$ from equation (12). Elliott *et al.* (1996, table 1) tabulate the critical values of this test statistics. As shown in table 2, the DF-GLS test does not reject the null of a unit root in productivity growth since the t -ratio for a is below the 5 per cent critical value.

As a further check for robustness we consider the test MZ_α proposed by Ng and Perron (2001) which is a modification of the Phillips-Perron test. Notice that it is built upon the GLS detrending procedure. The authors use this procedure in conjunction with an autoregressive spectral density estimator at frequency zero in order to deal with problems related to the possible presence of negative serial correlation in the residuals. For both the DF-GLS and the MZ_α test we selected a lag length of 13 in the unit root regressions. As for the lag selection,

following the suggestions of Ng and Perron (2001), we used the modified Akaike information criterion (MAIC).

insert table 2 about here

Thus our results support the conclusion that labour productivity growth may be represented as a dynamic process with a unit root. A recent study by Staiger *et al.* (2002) concludes that in US postwar data (the sample period considered is 1959:1 - 2000:2) this series, though highly persistent, is trend-stationary. Ball and Moffitt (2002), instead, do not undertake formal investigations on the presence of unit roots and choose to isolate the long-run component of productivity growth by applying to the series the Hodrick-Prescott filter.

The different result we obtain with respect to Staiger *et al.* can be explained by two main factors. The first concerns the longer sample period considered in this paper, since we extend the research to the last quarter of 2004. The second and more important factor regards the possibility of utilizing some recently developed unit root tests which exhibit more power. In this context it is important to stress another serious problem, documented by Ng and Perron (2001), which affects traditional unit root tests. For the authors show that the ADF and the DF-GLS test suffer from low power and size distortions in the presence of a too small lag selection and in order to tackle the problem they have suggested using the modified Akaike information criterion (MAIC). Indeed, it is worth noticing that our selection of 13 lags based on MAIC is rather different with respect to the choice made by Staiger *et al.* which base their unit root tests on 6 lags.

5. Investigating the Presence of Long-Run Relations among Productivity Growth, Inflation and Unemployment

The detection of a unit root in productivity growth opens the way for the possibility of long-run equilibrium relations among the variables. We have already stressed that the recent analysis concerning the link among productivity growth, inflation and unemployment mainly maintains the assumption of a vertical Phillips curve and, more generally, excludes low-frequency effects of productivity shocks on inflation and unemployment. Yet, some recent researches (see *e.g.* Ireland, 1999 and Beyer and Farmer, 2003) have suggested that a positive long-run relation seems to characterize inflation and unemployment though the interpretative framework suggested in these papers does not attribute a role to

productivity growth. In this section we aim to show that, instead, an important role is likely to have been played by labor productivity growth in shaping the long-run behavior of inflation and unemployment

We start the empirical investigation concerning the presence of long-run equilibrium relations by estimating the following reduced form:

$$\Gamma(L)\Delta X_t = \mu - \gamma\beta'X_{t-1} + e_t \quad (14)$$

where the (3×1) vector $X_t = [\pi_t, u_t, \bar{y}_t]'$ contains $I(1)$ series and e_t is the (3×1) vector of disturbances such that $E(e_t) = 0$ and $E(e_t e_t') = \Sigma_e$. Δ is the difference operator, L is the lag operator, $\Gamma(0) = I$ and μ is a constant vector. In general, considering a n -dimensional dynamic linear system, the rank, $r < n$, of the autoregressive total multipliers matrix $A(1) = \gamma\beta'$, is given by the number of independent long-run relations. Moreover, γ is a $(n \times r)$ matrix of loadings and β is a $(n \times r)$ matrix of cointegrating vectors. It is well known that for any non-singular $n \times n$ matrix, Q , such that $\gamma_0 = \gamma Q^{-1}$ and $\beta'_0 = Q\beta'$, we obtain $A(1) = \gamma\beta' = \gamma_0\beta'_0$. It then follows that some meaningful identifying restrictions are required for identification. It is shown that exact identification of the cointegrating vectors is achieved by imposing r normalizations, one for each vector, and $r - 1$ restrictions for each row, i.e. a total of r^2 independent restrictions. Note that a sufficient rank condition also needs to be satisfied. Johansen (1995) has proposed a theorem in order to check that the restrictions imposed allow selection of an actually identified structure.

When we carry out the Johansen trace test (see table 3) we find that the hypothesis of two cointegrating relations cannot be rejected at the 2.5 percent level. It is worth noting that in this multivariate context it is also possible to make tests for stationarity of the variables and the results confirm the presence of a stochastic trend for all the three variables.

From here on, we have to find economically-meaningful restrictions in order to recover a long-run economic structure. The economic model presented in section 2 suggests that a long-run relation between productivity growth and unemployment may characterize the cointegration space. A second relation concerns a possible low-frequency relation between productivity growth and inflation. Hence, we recover the following exactly identified long-run model:

$$\beta'_0 X = \begin{pmatrix} 1 & 0 & \beta_{13} \\ 0 & 1 & \beta_{23} \end{pmatrix} \begin{pmatrix} \pi \\ u \\ \bar{y}_t \end{pmatrix} \quad (15)$$

The results show (see table 3) that an inverse relation characterizes productivity growth and unemployment: changes in labor productivity induce a long-run movement in the opposite direction of unemployment. Note that in this case there is no ambiguity concerning the causality direction, since the error correction term does not significantly enter the productivity growth equation and hence there is one-way causality. On the other hand, an inverse relation also characterizes inflation and productivity growth but the adjustment coefficients are both significant at the 10 per cent level and thus there is presence of bidirectional influence between the variables.

Ireland (1999) gives a rather different explanation of the positive long-run relation between inflation and unemployment. He shows that an implication of the Barro-Gordon model is that if one assumes the presence of a unit root in the natural rate of unemployment then the inability of monetary authorities to credibly commit to an antinflationary policy allows the nonstationarity in the natural rate to be translated into the rate of inflation. An important consequence is that a linear combination of inflation and unemployment should exhibit stationarity. Ireland finds that in postwar US data the existence of a long-run equilibrium relation between inflation and unemployment cannot be rejected. Yet, the theoretical scheme faces some difficulties in explaining the short-run dynamics of the variables. Beyer and Farmer (2003), instead, base their explanation on the role played by non-stationary shocks to the aggregate demand as the common source of nonstationarity in inflation, unemployment and in the federal funds rate. In our view this explanation seems to suffer from a fundamental weakness: theoretical models generally predict that demand shocks induce movements in the opposite direction of inflation and unemployment. That is the contrary of what is observed, at least at low frequencies, in the US economy.

Nevertheless, we believe it is important to stress that there is a crucial distinction between the short-run and the long-run interaction characterizing the joint dynamics of inflation and unemployment: Namely, the long-run positive comovement between the variables does not preclude the existence of a short-run tradeoff. A recent assessment concerning such tradeoff is given in Mankiw (2001). The author maintains that the inverse short-run relation is essentially a statement regarding the role of monetary policy: when central banks undertake disinflationary policies they cause an increase in unemployment which is associated with a decrease in inflation. Ribba (2005) identifies a structural model which includes the same set of variables considered in Beyer and Farmer. He shows that as a consequence of both monetary policy shocks and aggregate demand shocks, inflation and unemployment are pushed in opposite directions. Moreover, in the long run these effects vanish and supply shocks play a pre-eminent role in accounting

for low-frequency movements in inflation and unemployment.

insert table 3 about here

6. Conclusions

The main contributions of this paper have consisted in showing that, as far as the US economy is concerned: (i) estimation of dynamic Phillips curves should include measures of productivity growth shocks, since we detected the presence of significant effects on the dynamics of inflation and unemployment for the postwar period. (ii) Contrary to some previous researches, we found that labor productivity growth may be well characterized as a process which exhibits a unit root. (iii) When we investigated the possible presence of long-run equilibrium relations, the hypothesis of two stationary linear combinations could not be rejected. We identified a low-frequency relation between inflation and productivity growth and a second relation between unemployment and productivity growth. Thus, the conclusion we draw is that an important role in shaping the inflation-unemployment relation has been played by fluctuations in productivity growth.

Our conclusions are partially in line with some recent results concerning the US economy. Ball and Moffitt (2002) and Staiger *et al.* (2002), among others, have shown that productivity growth may help to explain the virtuous behavior of inflation and unemployment in the second part of the 1990s. Nevertheless, with respect to these studies, we have taken a step further by detecting the presence of a stochastic trend in productivity growth and, not less important, by showing the presence of long-run effects of labor productivity shocks on inflation and unemployment. Moreover, with respect to some papers such as Ireland (1999) and Beyer and Farmer (2003), we offer a different explanation of the enigmatic long-run relation between inflation and unemployment which, in recent years, has captured the attention of policy-makers and researchers. For, the first author attributed a pre-eminent role to the intertemporally inconsistent conduct of monetary policy as a key explanation for the positive long-run relation between the variables. On the other hand, Beyer and Farmer base their explanation on the possibility of non-stationary shocks affecting the aggregate-demand side. Our explanation, instead, relies on permanent shocks hitting the supply side in the form of productivity growth shocks, and on a propagation mechanism founded on a slow adjustment of real wage targets to unexpected changes in labor productivity growth.

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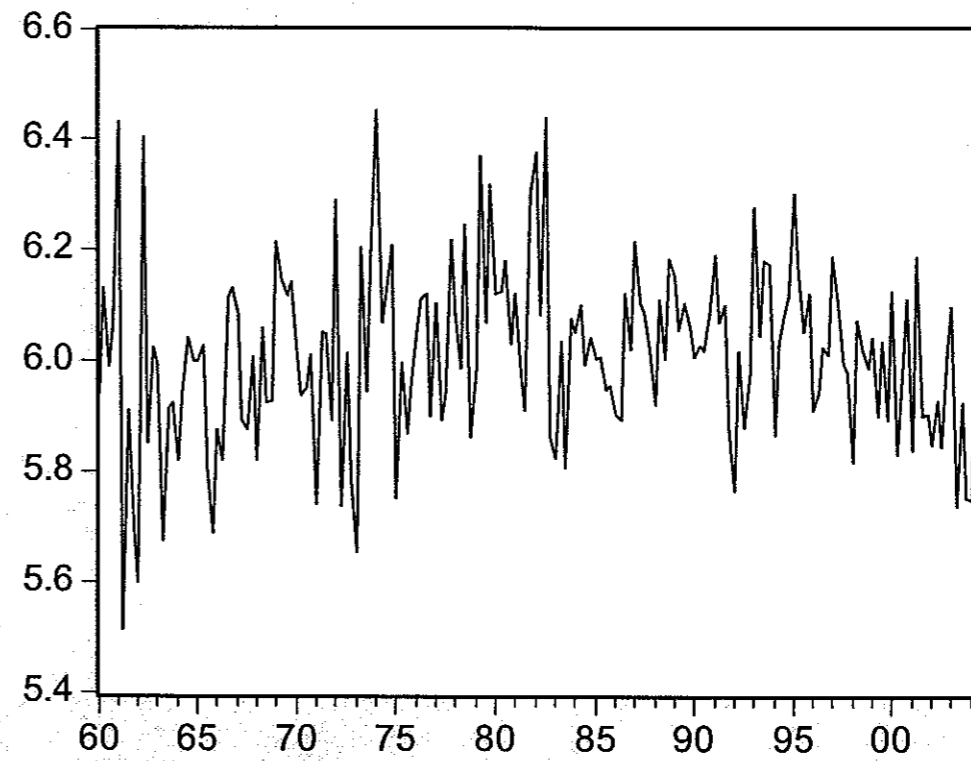


Figure 1. Estimated NAIRU

Table 1
Phillips Curve Estimates

| | Sample period 1960-2004 | Sample period 1970-1979 | Sample period 1983-1994 | Sample period 1995-2004 |
|-------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| Constant | .916 (.344) | 2.687 (1.254) | 1.135 (1.073) | -.141 (.776) |
| U | -.152 (.0569) | -.406 (.198) | -.195 (.161) | .042 (.278) |
| η_t | -.376 (.169) | -.762 (.435) | -.326 (.499) | -.809 (.301) |
| $\Delta\pi_{t-1}$ | .786 (.043) | .799 (.091) | .579 (.113) | .704 (.108) |
| ΔU_{t-1} | -.855 (.219) | -.569 (.525) | -1.01 (.441) | -.979 (.515) |
| R ² | .764 | .825 | .698 | .641 |

Notes. Estimated Model: $\Delta\pi_t = \tau - \alpha U_t - \phi\eta_t + \delta\Delta\pi_{t-1} - \psi\Delta U_{t-1}$.

Table 2
Unit Root Tests on Productivity Growth

| Test | Test Statistics | Test Critical Values (5% level) |
|---------------------|-----------------|------------------------------------|
| ADF | -2.2053 | -2.8774 |
| DF-GLS | -0.6627 | -1.9426 |
| MZ_{α}^{GLS} | -5.4454 | -8.1000 |

Notes. The sample period is 1960:1 – 2004:4. The unit root tests are conducted on a measure of productivity growth given by a four period average of the annual change of labor productivity growth in the business sector. As for the lag length selection procedures, we used the modified Akaike information criterion (MAIC) suggested by Ng and Perron (2001).

TABLE 3
Cointegration Analysis

| Hypothesis | r = 0 | r ≤ 1 | r ≤ 2 |
|--|-------------------------------|-------------------------------|------------------------------|
| Trace statistic | | | |
| Observed value | 39.17 | 20.83 | 4.10 |
| 97,5% critical value | 32.33 | 17.46 | 5.02 |
| Variable | π | u | g |
| Cointegrating Vectors: exactly identified structure | 1.0 0 | 0 1 | 3.608 (0.67) 1.768 (0.40) |
| Adjustment coefficients | .0359 (.021) -.0248 (.035) | .0248 (.010) -.0666 (.017) | -.039 (.012) .015 (.021) |
| H ₀ : The Cointegration space contains trend-stationary π $\chi^2(1) = 9.61$; p-value 0.002 | 1.0 | 0 | 0 |
| trend-stationary u $\chi^2(1) = 10.31$; p-value 0.001 | 0 | 1 | 0 |
| trend-stationary g $\chi^2(1) = 5.42$ p-value 0.02 | 0 | 0 | 1 |

Notes. Results for the period 1960:1-2004:4 are based on a reduced form model with 6 lags which includes CPI inflation, unemployment rate and labor productivity growth rate. The numbers in parentheses are standard errors. Johansen's likelihood ratio test of restrictions on the cointegrating vectors is distributed as a chi-squared with degrees of freedom equal to the number of restrictions tested.

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