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Marika Karanassou
Hector Sala
Dennis J. Snower

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of Labor

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**Marika Karanassou**
*Queen Mary, University of London*

**Hector Sala**
*Universitat Autònoma de Barcelona*

**Dennis J. Snower**
*Birkbeck College, University of London, CEPR and IZA Bonn*

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IZA

P.O. Box 7240
D-53072 Bonn
Germany

Tel.: +49-228-3894-0
Fax: +49-228-3894-210
Email: iza@iza.org

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# ABSTRACT

## The European Phillips Curve: Does the NAIRU Exist?*

This paper has two aims. First, it provides simple theoretical models that highlight two channels whereby monetary shocks have permanent real effects and the interactions between these channels. Second, it presents an empirical dynamic model, covering a panel of EU countries, and derives the implied long-run inflation-unemployment tradeoff. Our results suggest that the tradeoff is far from vertical. We also find that wage persistence plays a larger role than price persistence in generating the tradeoff, but that the two forms of persistence are complementary in giving monetary policy its long-run real effects. Our results call for a reassessment of the European macroeconomic experience.

JEL Classification: E2, E3, E4, E5, J3

Keywords: inflation, unemployment, Phillips curve, nominal inertia, monetary policy, business cycles, forward-looking expectations, homogeneous dynamic panels, panel unit root tests

Corresponding author:

Dennis Snower
Department of Economics
Birkbeck College
University of London
7 Gresse Street
London W1T 1LL
United Kingdom
Tel.: +44 20 7631 6408
Fax: +44 20 7631 6416
Email: DSnower@econ.bbk.ac.uk

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## 1. Introduction

The past decade has seen a strong revival of the NAIRU as a focal point of macroeconomic research. This work is not simply of academic interest; it has figured prominently in the research of international policy making institutions such as the European Commission, the European Central Bank, the US Federal Reserve, and the International Monetary Fund. It is also pursued actively in various government departments around the world, and thus presumably is having an influence on the formulation of macroeconomic policy. It is hard to overestimate the importance of the underlying policy issues. What is at stake, among other things, are the objectives and constraints of monetary policy and the division of responsibility between fiscal and monetary policy.

The aim of this paper is to shed new light on the tradeoff between inflation and unemployment in the European Union by calling into question the NAIRU interpretation. We will argue that the EU faces a long-run inflation-unemployment tradeoff and that, in addition, the adjustment of inflation and unemployment to money growth shocks is very gradual and delayed.

The mainstream analysis of inflation and unemployment rests on the standard assumption that economic agents make their demand and supply decisions on the basis of real variables alone and thus, in the long-run labor market equilibrium, a change in the money supply has no real effects; it simply changes all nominal variables in proportion. It was on the basis of such money neutrality that Friedman (1968) and Phelps (1967) formulated the natural rate (or NAIRU) hypothesis, in which there is no permanent tradeoff between inflation and unemployment.

In the presence of money growth, time discounting and time-contingent nominal contracts, however, this argument no longer holds, as is recognized in the literature on the microfounded New Keynesian Phillips curve.[1] The rationale is straightforward. Under time-contingent nominal contracts, nominal variables are a weighted average of their past and future values. Under time discounting, the future receives less weight than the past. When the money supply grows, all nominal variables rise with the passage of time. However, as noted, the future (higher) values receive less weight than the past (lower) ones. Thus wages and prices do not keep pace with the money supply.

Accordingly, in the literature on the New Keynesian Phillips curve, the long-run inflation-unemployment is not vertical, but thus far the divergence from verticality was deemed unimportant. For example, a standard version of the microfounded New Phillips curve may be expressed as $\pi_t = \beta E_t \pi_{t+1} - \gamma (u_t - u^n) + \varepsilon_t$, where $\pi_t$ is the inflation rate, $u_t$ is the unemployment rate, $E_t$ denotes expectations set at time $t$, $\beta$ is

[1] Regarding Taylor contracts, see for example Helpman and Leiderman (1990), Ascari (2000), and Graham and Snower (2002); for Calvo contracts, see for example Bernanke, Gertler and Gilchrist (2000) and Galí (2003).

the discount factor, $\varepsilon_t$ is white noise, and $\gamma$, and $u^n$ are constants. Since the discount factor is close to unity, it is generally taken for granted that the long-run Phillips curve is close to vertical, so that $u^n$ is close to being the NAIRU.

We argue, however, that this argument is seriously misleading. The reason is twofold. First, discounting is not the only reason why agents attach less weight to the future than the past; uncertainty (and the associated risk premia) is another significant reason. Second, and more importantly, the standard derivation of the New Keynesian Phillips curve is based on a single nominal rigidity (viz, Calvo or Taylor adjustments of either prices or wages). When there are multiple nominal rigidities occurring simultaneously, the weighting effect above is considerably amplified. The reason, as we will show in the next section, is that the weighting effects associated with wages and prices are complementary with one another.

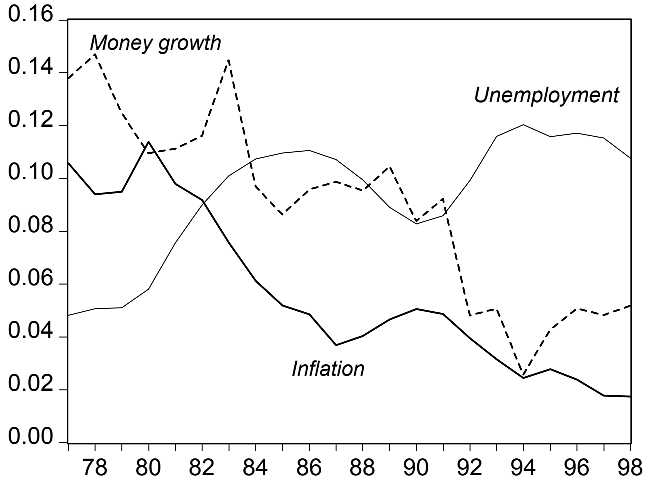
We then proceed to construct an empirical model of inflation and unemployment in the EU. This model aims to capture the interplay between money growth, lagged wage-price adjustments, and the implications for real economic activities. Accordingly, we estimate an equation system covering wages, prices, employment, labor force, output, and capital for a panel of EU countries. In this context, changes in money growth affect real balances and the real wage and thereby affect the other real variables, enabling us to evaluate the EU's long-run inflation-unemployment tradeoff. We find that the Phillips curve slope turns out to be reasonably flat. We conclude that it is time for a major rethink of the macroeconomic relation between real and nominal variables, and of the role of monetary policy.

Our paper is organized as follows. Section 2 compares our interpretation of EU macroeconomic activity with that provided by the traditional and New Phillips curves. Section 3 outlines a number of simple theoretical macroeconomic models to illustrate the channels whereby money growth has permanent effects on unemployment. Section 4 describes our empirical model. Section 5 presents our results. Section 6 concludes.

## 2. Underlying Issues

Figure 1 describes the EU inflation, unemployment and money growth rates over the past two decades. We observe (a) the rapid rise in unemployment from the late 1970s to the mid-1980s, accompanied by a rapid decline in money growth and inflation, (b) the modest decline in unemployment in the late 1980s, associated with a modest rise in money growth and inflation, and (c) the steep rise in unemployment in the early 1990s followed by a slight decline, along with a steep decline in money growth and inflation, followed by a slight rise.

**Figure 1. Inflation, unemployment and money growth in the EU**



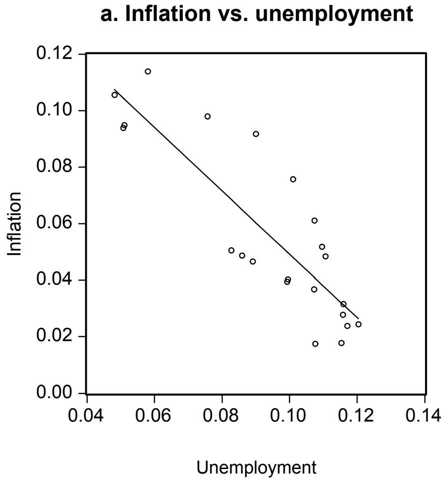

The original way of analyzing the relation between inflation and unemployment was through the *traditional Keynesian Phillips curve*, which (in its simplest form) may be expressed as $\pi_t = a\pi_{t-1} - bu_t + c + \varepsilon_t$, where $a$, $b$, and $c$ are positive constants ($0 < a < 1$). This Phillips curve was given no proper microfoundations, and it implied a stable long-run tradeoff between inflation and unemployment: $\pi = \frac{c}{1-a} - \frac{b}{1-a}u$.

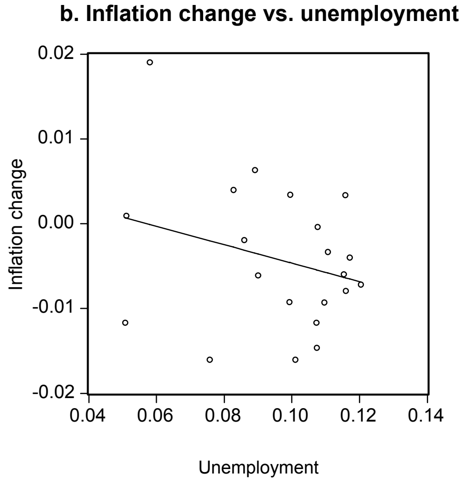
The seminal contributions of Phelps (1967) and Friedman (1968) argued, however, that there could be no such long-run tradeoff: in the absence of money illusion, labor demand and supply depend only on relative prices, and thus the long-run unemployment (the NAIRU or natural rate of unemployment) is associated with a real wage that is consistent with any level of wage and price inflation. This insight gave rise to the *expectations-augmented Phillips curve*, which can be written as $\pi_t = \pi_{t-1} - \gamma(u_t - u^n) + \varepsilon_t$, where $u^n$ is the NAIRU or natural rate, and expectations were proxied by past inflation. While this model has been modified and expanded in many ways,[2] the NAIRU feature is common to them all. This Phillips curve embodies the "accelerationist hypothesis" since unemployment can remain below (above) the natural rate only if the price level accelerates (decelerates) without limit.

If we assume that the NAIRU is stable through time then the traditional Phillips curve fit the European data better than the expectations-augmented Phillips curve. This is illustrated in the scatter plots of Figures 2: Fig. 2a plots inflation against unemployment, whereas Fig. 2b plots the change in inflation against unemployment. On this account, there is widespread agreement that the European NAIRU must have changed substantially over the sample period.

[2] A particularly popular extension is Gordon's (1982) triangle model, in which inflation depends on lagged inflation terms, an index of excess demand, and a vector of supply shock variables.

**Figure 2. Covariation in Inflation and Unemployment**




In particular, the upward ratchet in EU unemployment till 1994 must imply a gradual rise of the NAIRU. Had the NAIRU remained unchanged, the traditional Keynesian expectation-augmented Phillips curve would imply progressively greater disinflation, and that did not happen. Had there been no disinflation at all, the NAIRU would have had to match the rise in actual unemployment. As it was, the disinflation meant that the NAIRU rose by less than actual unemployment.

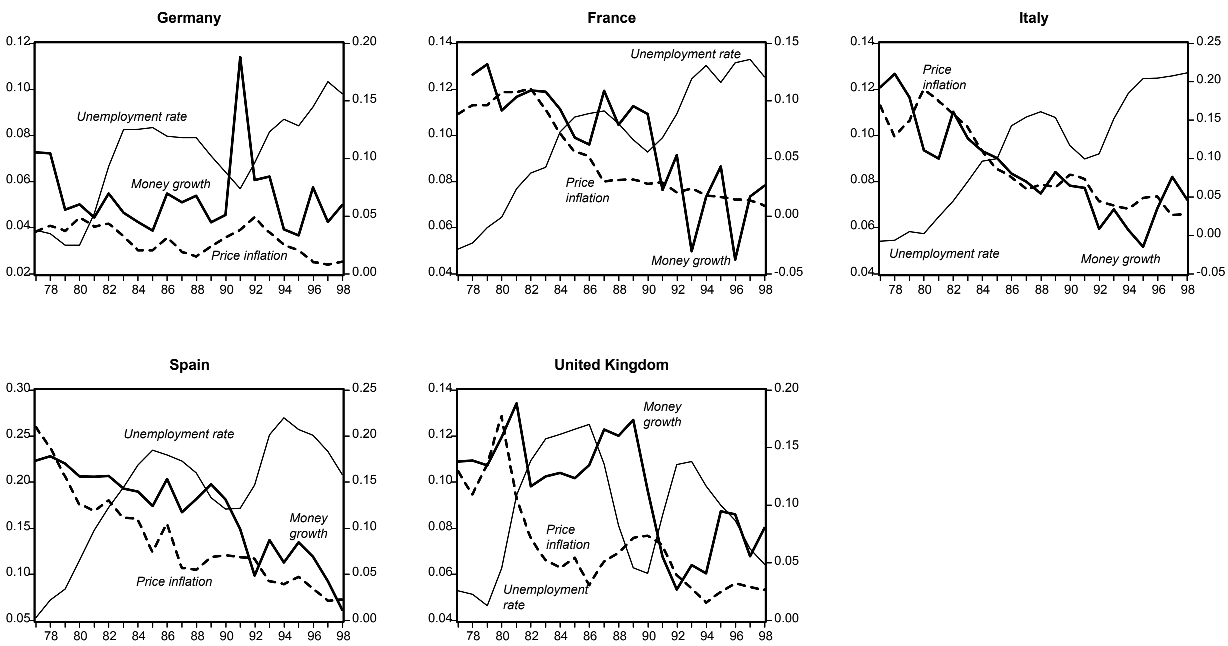
In the same vein, the expectations-augmented Phillips curve implies that the stable EU unemployment and declining inflation after 1994 imply a fall of the EU NAIRU. Furthermore, the moderate disinflation meant that the NAIRU declined by less than would have been required under constant inflation.

The New Phillips curve, whose standard textbook form $\pi_t = E_t\pi_{t+1} - \gamma\left(u_t - u^n\right) + \varepsilon_t$ is consistent with the NAIRU, has very different implications for the relation between unemployment and the change in inflation. In the absence of expectational errors, it may be expressed as $\Delta\pi_t = \gamma\left(u_{t-1} - u^n\right) - \varepsilon_{t-1}$, whereas the traditional Phillips curve may be written as $\Delta\pi_t = -\gamma\left(u_t - u^n\right) + \varepsilon_t$. Interpretting the EU macroeconomic experience in terms of the New Phillips curve, the disinflation of the 1980s implies that the NAIRU must have *risen by more* than the actual unemployment. Similarly, the disinflation after 1994 implies that the NAIRU must have *declined by more* than would have been necessary under constant inflation.

This paper offers a different interpretation of the movements in EU inflation and unemployment. It is that the long rise in unemployment and the long fall in inflation in the EU from the mid-1970s to the early 1990s represents a movement along a downward-sloping long-run Phillips curve. In contrast to the traditional Keynesian Phillips curve, ours is built on rigorous microfoundations and has distinct implications, discussed below. Our theoretical model (in the following section) shows why there can be a long-run Phillips curve tradeoff even in the absence of money illusion. Money illusion implies that when all nominal variables are changed in proportion, real variables remain unchanged. But under frictional growth, wages and prices do not change proportionately to the money supply. Since wages and prices are chasing after their moving (flexible) targets, changes in money growth lead to changes in the relation between wages and prices (on the one hand) and the money supply (on the other). By implication, there is no NAIRU.

Figure 3 shows the trajectories of inflation, unemployment, and money growth for the large EU countries: Germany, France, Italy, Spain and the UK. Observe that in the first four countries, the long-term rise in unemployment over the twenty-year period was accompanied by a long-term fall in money growth and the inflation rate. The UK trajectories are more complex, but it is nevertheless remarkable that here, too, unemployment moves in the opposite direction to money growth and inflation over most of the sample period. These patterns are consonant with our conception of a long-run downward-sloping Phillips curve.

**Figure 3. Inflation, unemployment and money growth in the G5 countries**




Testing whether the NAIRU exists is of course fraught with difficulties, particularly when the NAIRU is time-varying. We will argue that single-equation models of the Phillips curve, which are usual in the empirical literature, are not able to capture the phenomenon of frictional growth, since they cannot capture the interplay between money growth and nominal frictions. On the other hand, the phenomenon can be analyzed in a multi-equation context describing how nominal variables lag behind changes in money and how the real variables are influenced by these lagged responses. In this context, we will argue that the NAIRU exists when the long-run unemployment rate is independent of any nominal variables, and that there is no NAIRU when this long-run unemployment rate depends on some nominal variable, such as the rate of money growth.

For our empirical model of the EU, we will find that the NAIRU indeed does not exist in the above sense, and that thus monetary policy has permanent effects on unemployment. Needless to say, only a part of macroeconomic activity can be explained in this way. Much of the rest, our analysis suggests, can be explained by the prolonged after-effects of a variety of demand- and supply-side shocks on inflation and unemployment. We do not of course wish to suggest that the rise of EU unemployment is primarily due to contractionary monetary policies, but our analysis does imply that these policies were not irrelevant to long-run unemployment rates in the EU. Our challenge is to build a model that allows us to distinguish the long-run inflation-unemployment tradeoff generated by long-run changes in money growth from the responses to other shocks. For instance, we will need to distinguish the permanent unemployment effects of money growth shocks from the prolonged, but transient, effects.

## 3. Simple Macro Models

Our analysis rests on three empirical regularities: (i) the growth rate of the money supply is nonzero, (ii) there is some nominal inertia, so that a current nominal variable is slow to adjust to money growth shocks, and (iii) unemployment is influenced by the ratio of the nominal money supply to that nominal variable (such as the ratio of the money supply to the price level).

The first regularity provides a reasonable time-series description of the money supply in most OECD countries. The second stylized fact is well-established empirically and has been rationalized theoretically.[3] In the presence of staggered time-contingent nominal contracts, current wages are a weighted average of their past and expected future values. A well-known result in the literature on the microfoundations of wage-price staggering[4] is that when the rate of time discount is positive, the past is weighted

[3]See, for example, Taylor (1979) on wage staggering, Calvo (1983), or Lindbeck and Snower (1999) on price precommitment with production lags. The literature on the effectiveness of monetary policy under wage-price staggering has been surveyed by Clarida, Galí and Gertler (1999), Goodfriend and King (1997), Mankiw (2001), and others.

[4]For example, Ascari (2000), Ascari and Rankin (2002), Graham and Snower (2002), and Helpman and Leiderman (1990).

more heavily than the future. It is in this sense that current prices and wages may be taken to be characterized by nominal inertia. The third regularity can take a variety of conventional forms, e.g. a change in the ratio of the money supply to the price level may affect aggregate demand and thereby the unemployment rate.

We argue that when the money supply grows in the presence of nominal inertia, wages and prices lag behind the money supply. Thus changes in money growth can give rise to changes in real money balances and real wages, and these - in turn - influence unemployment.

This section presents some simple macroeconomic models that illustrate how this works. Specifically, they describe two channels whereby changes in money growth have permanent effects on inflation and unemployment. The first model describes the "real money balance channel," i.e. an increase in money growth affects long-run real money balances and thereby the long-run unemployment rate. The second model considers the "real wage channel," whereby an increase in money growth affects long-run unemployment via the real wage and employment. And the third model considers both channels operating in tandem.

The literature on the microfoundations of nominal contracts shows how, in the presence of time discounting, current wages and prices depend more heavily on past nominal values than on expected future ones.[5] Since there is no need to repeat these results here, our macro models take a short-cut: Instead of explaining wages and prices as a weighted average of past and expected future values, with past values receiving greater weight, we simply let them depend on past values alone. An alternative rationale for this short-cut is that, in the context of stochastic dynamic general equilibrium models, expected future values are of course expressible in terms of present and past endogenous variables. Thus our wage and price equations may be understood as simplified reduced forms of their structural counterparts. This short-cut vastly simplifies the algebra and thus clarifies the underlying mechanisms that generate the long-run inflation-unemployment tradeoff.

### 3.1. Model 1: The Real Money Balance Channel

In this model and the ones that follow, all variables - except the unemployment rate - are in logs. All uninteresting constants are ignored.

Since we wish to focus on the long-run inflation-unemployment tradeoff and since movements along this tradeoff arise from permanent changes in money growth, we need to specify any monetary policy rule that allows for such permanent changes. For the

[5] See Ascari (2000, 2001), Graham and Snower (2002), Helpman and Leiderman (1990), and Karanassou, Sala and Snower (2002). Further models in this spirit, though with less emphasis on time discounting are Chari, Kehoe and McGrattan (2000) and Huang and Liu (2002).

purposes of our analysis in this section, any such rule will suffice to generate our results on the long-run tradeoff. For example, we could assume that money growth follows a random walk, or that the monetary authority follows a Taylor rule in which there can be exogenous changes in the inflation target (associated with permanent changes in money growth). For expositional simplicity, however, we specify a simple money supply equation with the following rationale. Suppose that at a particular time $t$ the monetary authority makes a decision about which of two policies to pursue in the future. (One may, for instance, think of this decision as the outcome of an election, at time $t$, of the chairperson of the monetary policy committee.) With probability $\rho$, money growth $\mu_t$ follows a stationary autoregressive process $\mu_t = g_1 + \phi_1 \mu_{t-1} + \varepsilon_t$, and with probability $(1-\rho)$ it follows $\mu_t = g_2 + \phi_2 \mu_{t-1} + \varepsilon_t$, where $\varepsilon_t$ is a white noise error term, $0 < \phi_1, \phi_2 < 1$, and $\frac{g_1}{1-\phi_1} < \frac{g_2}{1-\phi_2}$. Thus the money supply rule can be summarized as

$$\Delta M_t \equiv \mu_t = g + \phi \mu_{t-1} + \varepsilon_t, \tag{3.1}$$

where $g = \rho g_1 + (1-\rho) g_2$, $\phi = \rho \phi_1 + (1-\rho) \phi_2$, and $M_t$ is the (log of the) money supply. Once the monetary authority's policy decision is made, the long-run money growth rate is either $g_1/(1-\phi_1)$ or $g_2/(1-\phi_2)$. This setup up allows us to consider two different points on a long-run Phillips curve (corresponding to the two long-run money growth rates).[6]

The current price level depends on the past price level and the money supply:

$$P_t = a P_{t-1} + (1-a) M_t, \tag{3.2}$$

where the "price sluggishness parameter" $a$ is a constant, $0 < a < 1$. This is the only substantive *ad hoc* simplification that this model makes in describing frictional growth. As noted, the microfoundations literature on price staggering indicates that the current price level is a weighted average of past and expected future price levels, with the past weighted more heavily than the future, under time discounting. Equation (3.2) provides a simplified picture of this source of price inertia and it thereby clarifies the mechanism whereby frictional growth generates a downward-sloping long-run Phillips curve.

Aggregate product demand depends on real money balances:

$$Q_t^D = (M_t - P_t). \tag{3.3}$$

[6] Moreover, since agents at time $t$ know the stochastic process (3.1) generating money growth, we can consider these points on the long-run Phillips curve without the danger of running afoul of the Lucas critique.

The aggregate production function is

$$Q_t^S = \sigma N_t, \tag{3.4}$$

where $\sigma$ is a positive constant[7]. The labor supply is constant:

$$L_t = L, \tag{3.5}$$

so that the unemployment rate (not in logs) can be approximated as

$$u_t = L - N_t. \tag{3.6}$$

Observe that money illusion is absent in system (3.1)-(3.6): if all nominal variables are changed in equal proportion, then the associated real variables remain unchanged. Nevertheless, it can be shown that there is a long-run inflation-unemployment tradeoff and that changes in money growth can move the economy along this tradeoff.

Defining the inflation rate as $\pi_t \equiv P_t - P_{t-1}$ and taking the first difference of the price equation (3.2), we obtain

$$\pi_t = a\pi_{t-1} + (1-a)\,\mu_t. \tag{3.7}$$

It is straightforward to show that, in this context, the long-run inflation rate is equal to the long-run money growth rate: $\pi_t^{LR} = \mu_t^{LR}$ (which bears the time subscript since money growth can obtain different values in the long-run).[8] Furthermore, long-run real money balances depend on the long-run money growth rate:[9]

$$(M_t - P_t)^{LR} = \frac{a}{1-a}\mu_t^{LR}. \tag{3.8}$$

[7] $\sigma = 1$ under constant returns to labor, and $\sigma$ is less (greater) than unity under diminishing (increasing) returns.

[8] To see this, rewrite equation (3.7) as $\pi_t = \mu_t - \frac{a}{1-a}\Delta\pi_t$. Thus, given structural stability, the long-run relationship between the inflation rate and the growth rate of money supply is

$$\pi_t^{LR} = \mu_t^{LR} - \frac{a}{1-a}\left(\Delta\pi_t\right)^{LR}. \tag{F1}$$

Now take the first difference of (3.7), $\Delta\pi_t = a\Delta\pi_{t-1} + (1-a)\,\Delta\mu_t$, and note that the long-run solution this equation is given by its unconditional expectation: $\left(\Delta\pi_t\right)^{LR} \equiv E\left(\Delta\pi_t\right)$. Taking expectations on both sides of the previous equation, we obtain

$$E\left(\Delta\pi_t\right) = 0, \text{ or } \left(\Delta\pi_t\right)^{LR} = 0, \tag{F2}$$

since $E\left(\Delta\pi_t\right) = E\left(\Delta\pi_{t-1}\right)$, due to stationarity, and $E\left(\Delta\mu_t\right) = 0$, by equation (3.1), where $E$ is the unconditional expectations operator.

Substitution of (F2) into (F1) yields $\pi_t^{LR} = \mu_t^{LR}$.

[9] To see this, note that equation (3.2) may be rewritten as $(1-a)\,M_t = (1-a)\,P_t + a\pi_t$, and recall that $\pi_t^{LR} = \mu_t^{LR}$.

Consequently, by (3.3)-(3.6) and (3.8), we obtain a long-run (steady-state) relation between unemployment and inflation:

$$\pi_t^{LR} = \sigma \left( \frac{1-a}{a} \right) \left( L - u_t^{LR} \right) \tag{3.9}$$

The long-run Phillips curve is flatter,

- the greater is the price sluggishness parameter $a$ and
- the greater is the curvature of the production function (i.e. the smaller $\sigma$).

It is straightforward to see the intuition underlying the downward slope of the Phillips curve. When the money supply grows, the price level chases after a moving target. But since the money supply keeps on increasing, the price adjustments never work themselves out entirely. By the time the current price level has begun to respond to the current increase in the money supply, the money supply increases again, prompting a new round of price adjustments. The greater is money growth, the greater will be the difference between the target and actual price levels (*ceteris paribus*). Thus a permanent increase in money growth not only increases long-run inflation, but also raises real money balances and thereby reduces unemployment in the long run. On this account, there is a long-run tradeoff between inflation and unemployment.

### 3.2. Model 2: The Real Wage Channel

Our second macro model deals with the real wage channel. To illustrate this channel as simply as possible, suppose that the price level adjusts instantaneously to the money supply:

$$P_t = M_t, \tag{3.10}$$

whereas the nominal wage is sluggish, depending on its past value and the current money supply:

$$W_t = bW_{t-1} + (1-b) M_t, \tag{3.11}$$

where $b$, the "wage sluggishness parameter," is a constant, $0 < b < 1$.

As in the previous section, the growth rate of money supply is given by equation (3.1). In this context, a change in the money growth regime leads to a change in the real wage. Employment, in turn, depends on the real wage:

$$N_t = c_0 - c_1 \left( W_t - P_t \right), \tag{3.12}$$

where $W_t - P_t$ is the log of the real wage, and the labor demand curve is derived from the production function (3.4), so that $c_0 = \frac{\log \sigma}{1-\sigma}$ and $c_1 = \frac{\sigma}{\sigma - 1}$. As in the previous section, the labor supply is constant (equation (3.5)), and the unemployment rate is given by equation (3.6).

Defining the rate of wage inflation as $\nu_t = W_t - W_{t-1}$, and taking the first difference of the wage equation (3.11), we obtain

$$\nu_t = b\nu_{t-1} + (1-b)\,\mu_t, \tag{3.13}$$

Thus the long-run rate of wage inflation is $\nu_t^{LR} = \pi_t^{LR}$. The long-run real wage depends on the long-run money growth rate:[10]

$$(W_t - P_t)^{LR} = \frac{-b}{1-b}\mu_t^{LR}. \tag{3.14}$$

The greater the long-run growth rate of the money supply, the lower is the corresponding long-run real wage. Thus greater is employment and the lower is unemployment in the long run.

To derive the associated long-run Phillips curve, observe that $\mu_t = \pi_t$ (by equation (3.10), recall that $\nu_t^{LR} = \pi_t^{LR}$, and use equations (3.12), (3.6) and (3.14) to obtain:

$$\pi_t^{LR} = \frac{1-b}{c_1 b}\left(L - u_t^{LR}\right) \tag{3.15}$$

This long-run Phillips curve is flatter,

- the greater is the wage sluggishness parameter $b$ and
- the greater is the slope of the labor demand curve $c_1$.

Once again, the intuition is clear. When the nominal wage is subject to more inertia than the price level then, in the presence of money growth, the wage chases after its moving wage target more slowly than the price chases after its moving price target. The faster the money supply grows, the more the price level rises relative to the nominal wage. Thus the real wage falls, labor demand rises, and unemployment falls.

An obvious deficiency of the real wage channel is that, on its own, it implies that real wages always move counter-cyclically, and this prediction is counterfactual. The evidence suggests that although real wages are counter-cyclical in some countries during some time periods, there are plenty of occasions in which they are pro-cyclical and acyclical. In practice, however, the real wage channel is unlikely to operate in isolation. When it is combined with the real money balance channel, for instance, the resulting

[10] To see this, rewrite the wage equation as $(1-b)\,P_t = (1-b)\,W_t + b\nu_t$.

real wages are no longer necessarily counter-cyclical, as shown below.[11] Furthermore, it is well to keep in mind that, in practice, the real wage moves in response to many determinants, of which the money supply is only one. Thus an inverse relation between the real wage and money growth may coexist with pro-cyclical real wage behavior.

### 3.3. Model 3: Both Channels

Our final macro model is concerned with the interplay between the two channels above, which turns out to have interesting implications for the long-run inflation-unemployment tradeoff. For this purpose, we consider a model in which there is lagged adjustment in both wages and prices. Specifically, let the money growth rate be given by equation (3.1), the price equation by (3.2), the wage equation by (3.11), labor supply by (3.5), and unemployment by (3.6):

$$\begin{aligned} \Delta M_t \equiv \mu_t &= g + \psi\mu_{t-1} + \varepsilon_t, \\ W_t &= bW_{t-1} + (1-b)\,M_t, \\ P_t &= aP_{t-1} + (1-a)\,M_t, \\ L_t &= L, \\ u_t &= L - N_t, \end{aligned}$$

where the price-, wage-, and money-sluggishness parameters are positive and less than one ($0 < a, b, \psi < 1$).

Furthermore, to enable both channels to operate, we extend the labor demand equation to allow employment to depend on both the real wage ($w_t \equiv W_t - P_t$) and real money balances ($M_t - P_t$)[12]:

$$N_t = c_0 - c_1 w_t + \frac{1}{\sigma}\left(M_t - P_t\right), \tag{3.16}$$

where the parameters $c_0, c_1$ and $\sigma$ are positive.

To derive the inflation-unemployment tradeoff in this setting, we first obtain the stochastic process for the real wage by subtracting the price equation (3.2) from the wage equation (3.11):

$$w_t = (a+b)\,w_{t-1} - abw_{t-2} - (b-a)\,\mu_t, \tag{3.17}$$

[11] The reason is that the impulse-response function of the real wage to money growth shocks need not be monotonic.

[12] The underlying assumption now is that changes in product demand (initiated by changes in real money balances) can influence the position of the labor demand function. Lindbeck and Snower (1994), for example, describe various microfounded channels whereby product demand changes can affect the labor demand function in the long run.

Next, note that the price equation (3.2) can be rewritten in terms of the real money balances:[13]

$$(M_t - P_t) = a(M_{t-1} - P_{t-1}) + a\mu_t. \tag{3.18}$$

Substitute equation (3.17) and (3.18) into the labor demand equation (3.16) to find how employment depends on its past values and money growth:

$$N_t = (a+b) N_{t-1} - abN_{t-2} + \left[c_1(b-a) + \frac{a}{\sigma}(1-b)\right]\mu_t + \frac{ab}{\sigma}\varepsilon_t. \tag{3.19}$$

Finally, by manipulation of equations (3.6) and (3.19) gives the following stochastic process for the unemployment rate:

$$u_t = (a+b) u_{t-1} - abu_{t-2} + (1-a)(1-b) L - \left[c_1(b-a) + \frac{a}{\sigma}(1-b)\right]\mu_t - \frac{ab}{\sigma}\varepsilon_t, \tag{3.20}$$

Thus the long-run unemployment rate is

$$u_t^{LR} = L - \left[\frac{\sigma c_1(b-a) + a(1-b)}{\sigma(1-a)(1-b)}\right]\mu_t^{LR}, \tag{3.21}$$

and the associated long-run Phillips curve is[14]

$$\pi_t^{LR} = \frac{\sigma(1-a)(1-b)}{\sigma c_1(b-a) + a(1-b)}\left(L - u_t^{LR}\right). \tag{3.22}$$

It can be shown that

- *The greater the wage sluggishness parameter $b$, the flatter is the long-run Phillips curve.*[15] The more sluggish is the nominal wage, the more will a given change in money growth reduce the real wage and thereby raise employment (*ceteris paribus*). Thus the greater will be the reduction in unemployment relative to the rise in inflation.

- *The greater is the price sluggishness parameter $a$, the flatter is the long-run*

[13] By equation (3.2),

$$P_t = aP_{t-1} + (1-a) M_t \Rightarrow (M_t - P_t) = aM_t - aP_{t-1}$$
$$(M_t - P_t) = aM_t - aP_{t-1} + aM_{t-1} - aM_{t-1} = a(M_{t-1} - P_{t-1}) + a\mu_t.$$

[14] Note that, in the context of this model, $b > a$ (more wage sluggishness than price sluggishness) is a sufficient condition for the Phillips curve to be downward-sloping. In this case, the money balance and real wage channels reinforce one another: an increase in money growth not only raises real money balances, but it also reduces the real wage (since the nominal wage responds less than the price level). But if $b < a$, the Phillips curve is still downward-sloping provided that $\sigma c_1 < \frac{a(1-b)}{(a-b)}$.

[15] To see this, let the slope (in absolute value) of the long-run Phillips curve be denoted by $\xi = \frac{\partial \pi_t^{LR}}{\partial u_t^{LR}} = \frac{\sigma(1-a)(1-b)}{\sigma c_1(b-a)+a(1-b)}$. Then observe that $\frac{\partial \xi}{\partial b} = -\frac{\sigma^2 c_1 (1-a)^2}{(\sigma c_1(b-a)+a(1-b))^2} < 0$.

*Phillips curve, provided that the real money balance channel dominates the real wage channel,* i.e. when $1/\sigma > c_1$ in the employment equation (3.16).[16] The more sluggish is the price level, the more will a given change in money growth raise real money balances as well as the real wage (*ceteris paribus*). Then, if the money balance channel dominates the real wage channel, the greater will be the rise in employment, and therefore the greater the fall in unemployment relative to the increase in inflation[17].

- *If the money balance channel dominates the real wage channel, then the wage sluggishness and price sluggishness are complementary in their influence in making the long-run Phillips curve flatter.* In particular,[18]

$$\frac{\partial^2 \xi}{\partial b \partial a} = \frac{2\sigma^2 c_1 (1-a)(1-b)(1-\sigma c_1)}{[\sigma c_1 (b-a) + a(1-b)]^3} > 0 \text{ if } \sigma c_1 < 1.$$

Although the theoretical models above provides a rationale for a long-run inflation-unemployment tradeoff, they are far too simple to guide us in assessing the effects of monetary shocks in the real world. Accordingly, we now turn to our empirical investigation of the inflation-unemployment tradeoff in the EU.

## 4. The Empirical Model

Our estimated dynamic structural model comprises a system of real and nominal equations and covers a panel of eleven EU countries.[19] The real equations include employment, labor force, capital, and output equations, and describe the responses of these variables to relative nominal magnitudes, real money balances and real wages. These relative nominal magnitudes, in turn, are influenced by monetary shocks, as described in the nominal equations, consisting of a wage and price equation. Simulating this model, we will then derive the implied long-run relation between inflation and unemployment in the EU.

We use annual data, defined in Table 1. The data sources are the OECD and Datastream. Our sample period of analysis is 1977-1998, due to data limitations.[20]

[16] Observe that $\frac{\partial \xi}{\partial a} = \frac{-\sigma(1-\sigma c_1)(1-b)^2}{[c_1(b-a)+ae(1-b)]^2} < 0$ if $\sigma c_1 < 1$.

[17] Conversely, if $\sigma c_1 > 1$, increased price sluggishness makes the Phillips curve steeper: $\frac{\partial \xi}{\partial a} > 0$.

[18] On the other hand, if the real wage channel dominates, then wage sluggishness and price sluggishness are substitutes ($\frac{\partial^2 \xi}{\partial b \partial a} < 0$, $\sigma c_1 > 1$).

[19] Austria, Belgium, Denmark, Germany, Finland, France, Italy, Netherlands, Spain, Sweden and the United Kingdom. Due to lack of data, Greece, Ireland, Luxembourg and Portugal are excluded from the analysis.

[20] There are two restrictions on our sample period: (1) 1977 is the first year in which information on French money supply is available from the sources above; and (2) national time series for money supply in the Euro area stopped in 1998, just before the introduction of EMU.

| **Table 1: Definitions of variables.** | | | |
|---|---|---|---|
| $M_t$ | money supply (M3) | $N_t$ | employment |
| $P_t$ | price level (GDP deflator) | $L_t$ | labor supply |
| $W_t$ | nominal wages | $u_t$ | unemployment rate $(L_t - N_t)$ |
| $w_t$ | real wage $(W_t - P_t)$ | $b_t$ | real social security benefits |
| $m_t$ | real money balances $(M_t - P_t)$ | $o_t$ | real oil prices |
| $\theta_t$ | real labor productivity | $\tau_t$ | indirect taxes as a % of GDP |
| $y_t$ | real GDP | $Z_t$ | working age population |
| $k_t$ | real capital stock | $t$ | linear time trend |
| $c_t$ | competitiveness defined as log (import prices) - log (GDP deflator) | | |
| All variables are in logs except for the unemployment rate $u_t$ and the tax rate $\tau_t$. Source: OECD and datastream. | | | |

In order to derive a long-run Phillips relation generated through frictional growth, we seek a convincing characterization of both the long run equilibrium and the temporal adjustment processes leading to it. Since this requires an ample number of observations, we use pooled estimation. Therefore, we have 242 observations (11 countries times 22 observations per country). The pooling of observations on a cross section of countries over several time periods can increase the efficiency of econometric estimates.[21] In our estimated system of equations, differences in economic behavior are depicted solely through fixed effects; i.e. differing constants in the estimated equations, while the coefficients for the endogenous regressors and exogenous variables are taken to be identical across countries.

### 4.1. Panel Unit Root Tests

In recent years, dynamic panel data and nonstationary panel time series models have attracted a lot of attention. As a result, the study of the asymptotics of macro panels with large $N$ (number of units, e.g. countries) and large $T$ (length of the time series) has become the focus of panel data econometrics.[22] In order to check if it is appropriate to use stationary panel data estimation techniques, we conduct a series of unit root tests. Although testing for unit roots in panels is recent,[23] it is generally accepted that the use of pooled cross-section and time series data can generate more powerful unit root tests.

In our empirical work we employ the simple statistic proposed by Maddala and Wu

[21] The advantages of using panel data sets for economic research are numerous and well documented in the literature. See, for example, Hsiao (1986) and Baltagi (1995) for a detailed exposition of stationary panel data estimation.

[22] Banerjee (1999) and Baltagi and Kao (2000), and Smith (2000) provide an overview of the above topics and survey the developments in this technical and rapidly growing literature.

[23] See, for example, Levin and Lin (LL) (1993), Im, Pesaran and Shin (2003), Harris and Tzavalis (1999), Maddala and Wu (1999). Note that the asymptotic properties of tests and estimators proposed for nonstationary panels depend on how $N$ (the number of cross-section units) and $T$ (the length of the time series) tend to infinity, see Phillips and Moon (1999).

(1999) to test for panel unit roots. This is an exact nonparametric test based on Fisher (1932):

$$\lambda = -2 \sum_{i=1}^{N} \ln \Pi_i \sim \chi^2 (2N), \tag{4.1}$$

where $\Pi_i$ is the probability value of the ADF unit root test for the $i$th unit (country). The Fisher test has several attractive features. First, since it combines the significance of $N$ different independent unit root statistics, it does not restrict the autoregressive parameter to be homogeneous across $i$ under the alternative of stationarity. Second, the choice of the lag length and of the inclusion of a time trend in the individual ADF regressions can be determined separately for each country. Third, the sample sizes of the individual ADF tests can differ according to data availability for each cross-section. Finally, it should be noted that the Fisher statistic can be used with any type of unit root test. Maddala and Wu (1999), using Monte Carlo simulations, conclude that the Fisher test outperforms both the Levin and Lin (1993)[24] and the Im, Pesaran and Shin (2003) tests.[25]

Table 2 reports the Fisher statistics for all the variables used in our structural equations. The null hypothesis is that the time series has been generated by an $I(1)$ stochastic process, and the test follows a chi-square distribution with 22 degrees of freedom (the 5% critical value is approximately 34). Note that all the panel unit root test statistics are greater than the critical value, so the null of a unit root can be rejected at the 5% significance level. Thus we canproceed with stationary panel data estimation techniques.

**Table 2: Panel Unit Root Tests.**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $\lambda(y_{it})$ | = | 42.88 | $\lambda(o_{it})$ | = | 42.67 | $\lambda(m_{it})$ | = | 38.28 |
| $\lambda(k_{it})$ | = | 41.19 | $\lambda(c_{it})$ | = | 46.79 | $\lambda(\Delta P_{it})$ | = | 36.26 |
| $\lambda(N_{it})$ | = | 36.10 | $\lambda(Z_{it})$ | = | 40.57 | $\lambda(\Delta W_{it})$ | = | 62.31 |
| $\lambda(L_{it})$ | = | 35.12 | $\lambda(b_{it})$ | = | 91.45 | $\lambda(\Delta M_{it})$ | = | 47.44 |
| $\lambda(w_{it})$ | = | 159.79 | $\lambda(\tau_{it})$ | = | 46.24 | $\lambda(W - M_{it})$ | = | 35.70 |

Notes: $\lambda(\cdot)$ is the test proposed by Maddala and Wu (1999).
The test follows a chi-square (22) distribution.
The 5% critical value is approximately 34.

[24] See also Levin, Lin and Chu (2002).

[25] LL proposed asymptotic panel unit root tests which are based on pooled regressions. The major criticism against the LL tests is that, under the alternative of stationarity, the autoregressive coefficient is the same across all units (i.e. $H_1 : \rho_1 = \rho_2 = ... = \rho_N = \rho < 0$).

This restrictive assumption is relaxed in the asymptotic test proposed by Im, Pesaran and Shin (IPS) (2003). Like the Fisher test, and in contrast to the LL tests, the IPS test is based on the individual ADF regressions for each of the $N$ cross-section units. While the Fisher test uses the probability values of the individual ADF tests, the IPS uses their test statistics. Compared to the Fisher test, the disadvantage of the IPS test is that it implicitly assumes the same $T$ for all countries and the same lag length for all the individual ADF regressions.

### 4.2. Estimation of stationary dynamic panel data models

We estimate the short-run and long-run parameters of behavioral relationships by using dynamic panel data models, i.e. models characterized by the presence of lagged dependent variables among the regressors, such as[26]

$$y_{it} = \alpha y_{i,t-1} + \beta' x_{it} + \varepsilon_{it}, \tag{4.2}$$

where $\alpha$ is a scalar, $\beta$ is a $K \times 1$ vector of constants, and $x_{it}$ is a $K \times 1$ vector of explanatory variables. The disturbances are assumed to follow a one-way error component model[27]

$$\varepsilon_{it} = \mu_i + \nu_{it},\ i = 1, ..., N,\ t = 1, ..., T, \tag{4.3}$$

where $\nu_{it} \sim iid\left(0, \sigma_\nu^2\right)$ with $Cov\left(\varepsilon_{it}, \varepsilon_{jt}\right) = 0$, for $i \neq j$. The scalar $\mu_i$ represents the effects that are specific to the $i$th unit and are assumed to remain constant over time. In this case, equations (4.2)-(4.3) give the fixed-effects (FE) model: slope coefficients and variances are identical across groups and only intercepts are allowed to vary. Note that the FE estimator[28] is the most common estimator for dynamic panels. In homogenous dynamic panels (i.e. models with constant slopes: $\alpha_i = \alpha$, and $\beta_i = \beta$) the FE estimator is consistent as $T \to \infty$, for fixed $N$.[29]

Baltagi and Griffin (1997) use a panel data set for 18 OECD countries with annual data covering the period 1960-1990, and compare the performance of a large number of homogenous and heterogeneous estimators in the context of dynamic demand for gasoline. They find that the individual country estimates (both OLS and 2SLS) exhibit substantial variability, suggesting that "the individual country estimates are highly unstable and unreliable," and they find that pooled estimators provide more plausible estimates. Baltagi and Griffin justify the use of pooled estimators by concluding that "the efficiency gains from pooling appear to more than offset the biases due to intercountry heterogeneities".[30]

[26] For expositional simplicity, we ignore higher order lags in equation (4.2).

[27] Again, we do not present the two-way error component model for expositional simplicity. However, we used time-specific effects ($\lambda_t$) in our estimations and for some of our structural equations these appear in the form of a time trend.

[28] The fixed-effects estimator is also known as the least squares dummy variables (LSDV) estimator, or the within-group or the analysis of covariance estimator.

[29] Kiviet (1995) showed that the bias of the FE estimator in a dynamic model of panel data has an approximation error of $O\left(N^{-1}T^{-3/2}\right)$. Therefore, the FE estimator is consistent only as $T \to \infty$, while it is biased and inconsistent when $N$ is large and $T$ is fixed.

[30] Baltagi and Griffin (1997) also find that "the gains from correcting for possible endogeneity in the lagged dependent variable are disappointing as the 2SLS estimators performed worse than their counterparts assuming all variables are exogenous". In particular, they note that standard pooled estimators give larger long-run elasticities (i.e. larger autoregressive parameters) than their 2SLS counterparts. Although they acknowledge the role of bias, they suspect that low autoregressive coefficients are simply due to poor instruments: "Current and lagged values of the exogenous variables

In this context, we now turn to the estimation of our dynamic panel using the fixed effects estimator.

### 4.3. The model

Our estimated system is given in Tables 3a and 3b.[31] The nominal equations are quite standard. Wages depend negatively on unemployment and positively on productivity, social security benefits, and oil prices. Prices depend negatively on productivity and positively on the oil price and output. These nominal equations may be interpreted as a natural extension of our theoretical model to include staggered contracts of both wages and prices. Thus, in the empirical model, past nominal values affect the current wage differently from the current price. As our theory suggests, wages and prices depend on the money supply, and we impose money neutrality, so that each nominal equation is homogeneous of degree zero in all nominal variables. Specifically, we restrict the coefficient of money in each of our nominal equations to be equal to one minus the coefficients of all nominal variables on the right-hand side of that equation.[32] Whereas the wage equation may be interpreted as based on a wage contract equation such as the one described above, the price equation may be understood as derived from a labor demand function substituted into a product market equilibrium condition.[33]

produce instruments that do not closely explain the lagged dependent variable."

[31] Country-specific coefficients and misspecification tests are available upon request.

[32] For example, consider the price equation in Table 3a: $P_t = a_0 + a_1 P_{t-1} + a_2 P_{t-2} + (1 - a_1 - a_2) W_t + \beta' x_t$, where $\beta'$ is a row vector of parameters, and $x_t$ is a column vector of the real variables. The above can be reparameterized as $(P_t - W_t) = a_0 + a_1 (P_{t-1} - W_{t-1}) + a_2 (P_{t-2} - W_{t-2}) - (a_1 + a_2) \Delta W_t - a_2 \Delta W_{t-1} + \beta' x_t$.

Clearly, the above price equation is homogeneous of degree zero in $W_t$, $P_t$, $P_{t-1}$. The analogous restriction has been imposed on the wage equation in Table 3a.

[33] Thus the price equation is distinct from the labor demand equation, given below.

**Table 3a: EU model, 1977-1998.**

| Dependent variable: $W_t$ | coef. | std. e. | Dependent variable: $P_t$ | coef. | std. e. | Dependent variable: $L_t$ | coef. | std. e. |
|---|---|---|---|---|---|---|---|---|
| $W_{t-1}$ | 1.02 | 0.050 | $P_{t-1}$ | 1.13 | 0.068 | $L_{t-1}$ | 0.82 | 0.055 |
| $W_{t-2}$ | -0.17 | 0.049 | $P_{t-2}$ | -0.34 | 0.054 | $L_{t-2}$ | -0.17 | 0.047 |
| $P_t$ | 0.87 | 0.063 | $W_t$ | 0.21 | (*) | $w_t$ | 0.025 | 0.012 |
| $P_{t-1}$ | -0.74 | 0.065 | $\theta_t$ | -0.27 | 0.027 | $\Delta w_t$ | -0.43 | 0.051 |
| $M_t$ | 0.01 | (*) | $o_t$ | 0.004 | 0.002 | $u_t$ | -0.21 | 0.035 |
| $u_t$ | -0.36 | 0.051 | $y_t$ | 0.15 | 0.048 | $Z_t$ | 0.35 | (+) |
| $\theta_t$ | 0.61 | 0.064 | $y_{t-1}$ | -0.11 | 0.047 | | | |
| $\theta_{t-1}$ | -0.55 | 0.062 | | | | | | |
| $o_t$ | 0.004 | 0.002 | | | | | | |
| $b_t$ | 0.11 | 0.026 | | | | | | |
| $b_{t-1}$ | -0.15 | 0.040 | | | | | | |
| $b_{t-2}$ | 0.10 | 0.028 | | | | | | |

$\Delta$ denotes the difference operator;
(*) restricted coefficient for no money illusion in the long-run;
(+) coefficient restricted so that the long-run elasticity with respect to $Z_t$ is unity.

Our real equations may be motivated as follows. We have a labor force and employment equations, since unemployment is the difference between these two variables.[34] In addition, we have a capital and output equation, since capital and labor are demanded conjointly by firms to produce output. The output and employment equations generate productivity, which influences wages and prices. These real equations are also standard. The labor force depends on the real wage, unemployment (via a discouraged worker effect), and population. We restrict the coefficient on population so that the long-run elasticity of the labor force with respect to population is unity. Employment depends negatively on the real wage and positively on productivity, competitiveness, and real money balances (which may be interpreted as playing an analogous role as real interest rates). Finally, output is produced by means of capital and labor. We impose constant returns to scale on the production function.

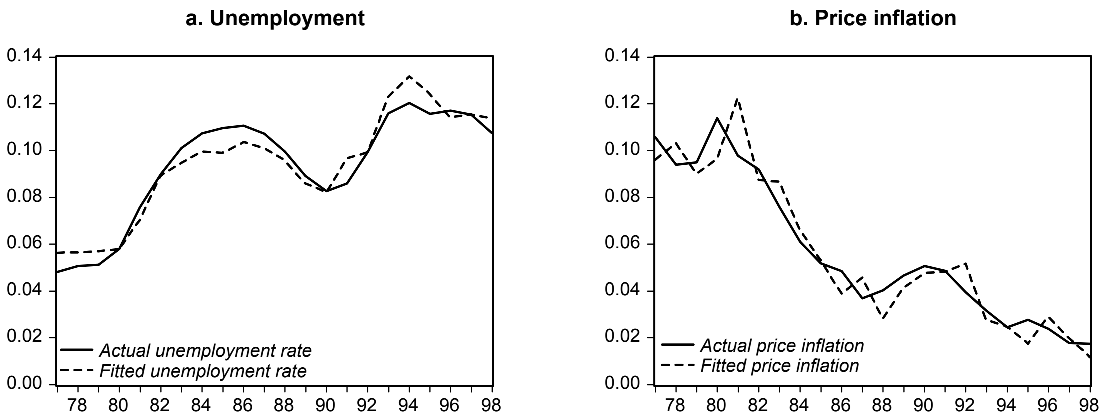
[34]Specifically, the unemployment rate may be approximated as the difference between the logarithms of the labor force and employment.

| Table 3b: EU model, 1977-1998. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Dependent variable: $N_t$ | | | Dependent variable: $k_t$ | | | Dependent variable: $y_t$ | | |
| | coef. | std. e. | | coef. | std. e. | | coef. | std. e. |
| $N_{t-1}$ | 1.04 | 0.049 | $k_{t-1}$ | 1.49 | 0.055 | $y_{t-1}$ | 0.85 | 0.040 |
| $N_{t-2}$ | -0.18 | 0.047 | $k_{t-2}$ | -0.51 | 0.054 | $N_t$ | 0.10 | (*) |
| $w_t$ | -0.19 | 0.032 | $w_t$ | -0.05 | 0.015 | $k_t$ | 0.05 | 0.024 |
| $m_t$ | 0.04 | 0.007 | $m_t$ | 0.01 | 0.003 | $\Delta k_t$ | 0.55 | 0.121 |
| $\theta_t$ | -0.72 | 0.068 | $\theta_t$ | -0.28 | 0.030 | $t$ | 0.002 | 0.0006 |
| $\theta_{t-1}$ | 0.82 | 0.065 | $\theta_{t-1}$ | 0.45 | 0.038 | | | |
| $c_t$ | 0.02 | 0.012 | $\theta_{t-2}$ | -0.13 | 0.030 | | | |
| | | | $o_t$ | -0.003 | 0.001 | | | |
| | | | $\tau_t$ | -0.084 | 0.052 | | | |

$\Delta$ denotes the difference operator;
(*) restricted coefficient for constant returns to scale.

The fitted values from our estimated model track the data well, as shown in Figure 4.[35]

**Figure 4. EU unemployment and price inflation: actual and fitted values**




# 5. Results

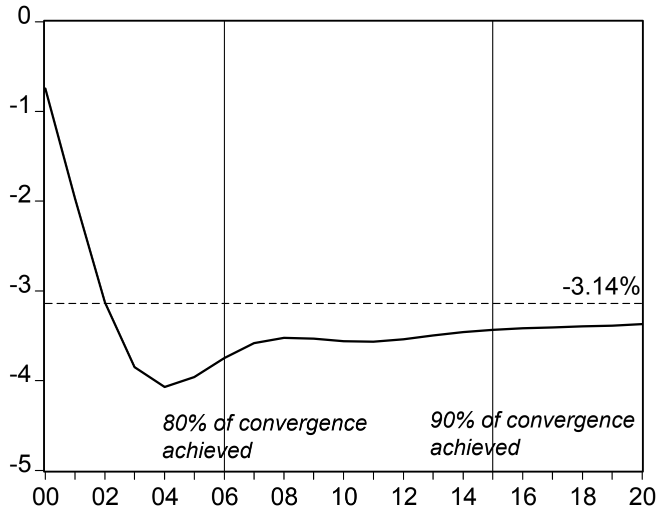
## 5.1. The long-run inflation-unemployment tradeoff

To obtain the long-run inflation-unemployment tradeoff, we impose a permanent 10% increase in money growth in yesr $t = 0$ and simulate the model forward. The absence

[35] The aggregate unemployment rate series are computed by taking the difference between the sum of the countries' labor forces and employment levels. The aggregate measure of inflation weights yearly each individual price inflation rate by the corresponding country weight in the aggregate EU GDP, expressed in PPP. The use of this measure, available for all countries and years, guarantees country comparisons which take into account national prices and exchange rate variations.

of money illusion condition ensures that price inflation converges to 10%. We find that the long-run unemployment rate is reduced by 3.14 percentage points. This implies that the slope of the long-run Phillips curve is -3.18 $\left(= \frac{10}{-3.14}\right)$.

**Figure 5. Real effects of monetary shocks**
**Unemployment response to a 10% permanent increase in money growth**




Since this long-run tradeoff is generated through frictional growth, let us explore how the tradeoff depends on the degree of nominal sluggishness. To assess the influence of price persistence, we reduce each of the autoregressive coefficients in the price equation by 10% and simulate the model.[36] The influence of wage persistence may be calculated analogously. The results are given in Table 4, which shows both the individual and joint effects of price and wage persistence.

[36]Note that the absence of money illusion restriction continues to hold despite the change in persistence. This can be seen by writing the price equation as $P_t = a_0 + a_1 P_{t-1} + a_2 P_{t-2} + (1 - a_1 - a_2) W_t + \beta' x_t$,where $x_t$ is a vector of the real variables. We reduce the autoregressive coefficients by 10% as follows:

$$(1 - 0.1a_1 - 0.1a_2) P_t = a_0 + 0.9a_1 P_{t-1} + 0.9a_2 P_{t-2} + (1 - a_1 - a_2) W_t + \beta' x_t.$$

Note that the above exercise does not affect the steady-state solution of the equation and, consequently, the restriction of no money illusion is still valid.

**Table 4: Price-wage stickiness and the long-run PC trade-off.**

| Simulated models | $\Delta P_t^{lr}$ | $u_t^{lr}$ | *PC slope* |
|---|---|---|---|
| (1) Full persistence | 10.0 | -3.14 | -3.18 |
| (2) Price persistence reduced by 10% | 10.0 | -2.72 | -3.68 |
| (3) Wage persistence reduced by 10% | 10.0 | -1.52 | -6.58 |
| (4) Price and wage persistence reduced by 10% | 10.0 | -1.10 | -9.09 |

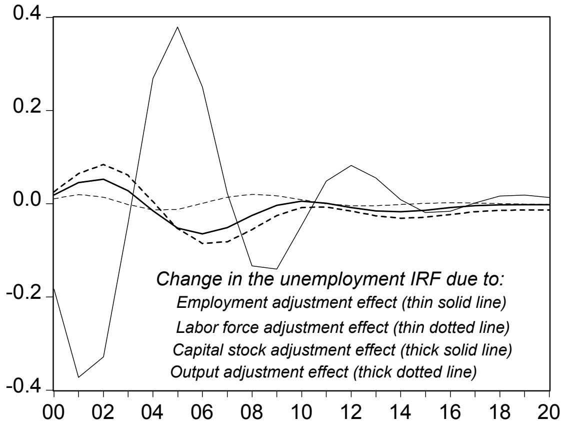
| | |
|---|---|
| Individual price effect: | (1)-(2)=0.5 |
| Individual wage effect: | (1)-(3)=3.4 |
| Sum of individual effects: | 0.5+3.4=3.9 |
| Joint effects: | (1)-(4)=5.9 |

Not surprisingly, the reductions in price and wage persistence each increase the slope of the Phillips curve: the lower the degree of persistence, the closer prices and wages come to their moving targets and thus the smaller are the real effects of an increase in money growth. Note that our estimated model indicates that wage persistence plays a much stronger role than price persistence in generating the long-run inflation-unemployment tradeoff.

Furthermore, observe that the effect of a joint reduction in price and wage persistence is greater than the sum of the individual effects, as shown in the last row of Table 4. This implies that price and wage persistence are complementary in generating the long-run inflation-unemployment tradeoff.

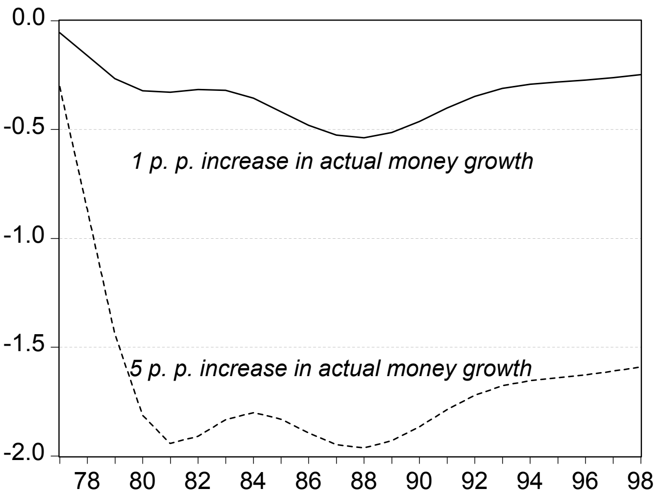
Figure 6 describes the influence of the real rigidities (the lagged adjustment of real variables). We consider the following: an *employment adjustment effect* (lagged employment in the employment equation), a *labor force adjustment effect* (lagged labor force in the labor force equation), a *capital stock adjustment effect* (lagged capital stock in the capital stock equation), and an *output adjustment effect* (lagged output in the output equation). It is important to observe that these effects influence the impulse-response functions of unemployment to a permanent money shock, but not the slope of the long-run Phillips curve. The reason is that they do not affect the steady-state levels of the real variables. The figure shows how the unemployment impulse-response function is affected by a 10% reduction in the respective autoregressive coefficients. We see that these effects are, perhaps surprisingly, quite weak. The employment adjustment effect is the strongest of the group.

**Figure 6. The Influence of Real rigidities**
**(persistence is reduced by 10% in each real equation)**




Finally, Figure 7 describes what happens to the unemployment rate over the sample period in our model when money growth is reduced by 1 and 5 percentage points in all of the EU countries. This is of course no more than a dynamic accounting exercise, since we are naturally unable to observe whether the dynamic responsiveness of nominal and real variables change in response to these changes in monetary regime.

**Figure 7. Changes in unemployment rates for different money growth rates**




### 5.2. GMM estimates of a single-equation Phillips curve

Before concluding, let us compare the above estimates of the long-run inflation-unemployment tradeoff with GMM estimates of a standard hybrid single-equation Phillips curve, obtained by using aggregate annual data for the whole EU, with a sample period running from 1972.[37]

The main difference between this single-equation Phillips curve and the ones usually examined in the literature is that we use our variable of interest, the unemployment rate, as the driving force variable, rather than the marginal cost or the output gap.[38]

Table 5 presents our results for two models. In the first, both the price inflation and unemployment are instrumented; whereas in the second, the latter variable is not instrumented.[39]

**Table 5: Phillips curve GMM estimates. EU, 1972-2001.**

Dependent variable is inflation $\pi_t$

| Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|
| | coef. | std. e. | | coef. | std. e. |
| $Cnt.$ | 0.025 | 0.005 | $Cnt$ | 0.024 | 0.005 |
| $\pi_{t+1}$ | 0.22 | 0.092 | $\pi_{t+1}$ | 0.24 | 0.084 |
| $\pi_{t-1}$ | 0.70 | 0.063 | $\pi_{t-1}$ | 0.69 | 0.058 |
| $u_t$ | -0.25 | 0.065 | $u_t$ | -0.24 | 0.044 |
| $R^2$ | 0.95 | | $R^2$ | 0.95 | |
| Long-run PC slope: | -3.13 | | Long-run PC slope: | -3.43 | |
| Instruments: $Cnt$, $\pi_{t-1}$, $\pi_{t-2}$, $u_{t-1}$, $u_{t-2}$, $o_t$, $\Delta\theta_t$, $\Delta Z_t$, $\Delta N_t$. | | | Instruments: $Cnt$, $\pi_{t-1}$, $\pi_{t-2}$, $u_t$, $u_{t-1}$, $u_{t-2}$, $o_t$, $\Delta\theta_t$, $\Delta Z_t$, $\Delta N_t$. | | |
| Validity of the instruments: | | | Validity of the instruments: | | |
| F-test ($\pi_{t+1}$)= 45.3[0.00] | | | F-test ($\pi_{t+1}$) = 41.3[0.00] | | |
| F-test ($u_t$) = 1146[0.00] | | | | | |
| $\chi^2$ (5) =3.43[0.63] | | | $\chi^2$ (6) =3.63[0.73] | | |

Observe that regardless of whether we instrument the unemployment rate, we obtain a non-vertical long-run PC slope, with a long-run trade-off very similar to the one derived from our multi-equation system.[40] It is also worth noting that the coefficient on the lag is about three times the coefficient on the lead, suggesting that backward-looking behavior has a stronger influence than forward-looking behavior.

[37] Since we do not use money supply, the sample period is larger than the one used in the panel data model. It starts in 1972, since aggregate EU data starts in 1970, and ends up in 2001 (not in 1998).

[38] See, for example, Bårdsen, Jansen, and Nymoen (2002), Galí and Gertler (1999), Galí, Gertler and López-Salido (2001), Lindé (2002), and Rudd and Whelan (2001).

[39] Both regressions are well-specified, and the F-statistics show a strong correlation between the endogenous variables and the list of instruments (see Staiger and Stock (1997)). Furthermore, the chi-square test for overidentifying restrictions (J-test times the no. of observations) indicates the validity of the instruments.

[40] It is important to emphasize, however, that - as in the rest of the literature in this area - our estimates are sensitive to the specification of the driving variables and instruments.

## 6. Concluding Thoughts

In this paper we have overviewed a theoretical case for a long-run inflation-unemployment tradeoff (in the presence of rational expectations, no permanent nominal rigidities, and no money illusion), and we have estimated a dynamic model (covering a panel of EU countries) and derived the implied tradeoff. Our results suggest that the tradeoff is far from vertical: a 10 percent increase in long-run money growth (equal to long-run inflation) is associated with a 3.18 percentage point fall in the EU unemployment rate. The model also implies that convergence to the long-run is very slow, and that in the interim the influence of monetary policy on unemployment is even greater.

A number of prominent contributors to the recent literature on the Phillips curve have commented that the conventional acceptance of the NAIRU or natural rate of unemployment - implying a vertical long-run Phillips curve - is a better reflection of theoretical preconceptions than empirical evidence. For example, Blanchard and Fischer (1989) state that "Most economists who came to accept the view that there was no long-run tradeoff between inflation and unemployment were more affected by a priori argument than by empirical evidence". Mankiw (2001) writes that "if one does not approach the data with a prior favoring long-run neutrality, one would not leave the data with that posterior. The data's best guess is that monetary shocks leave permanent scars on the economy". This paper shows what we find when we do not view the data with a preconceived attachment to the NAIRU.

We have also examined the role of price and wage persistence in generating the long-run Phillips curve tradeoff. We find that wage persistence plays a larger role than price persistence, but that the two forms of persistence are complementary in giving monetary policy is long-run real effects.

Our results call for a reassessment of the European macroeconomic experience. Instead of explaining the ascending swings of European unemployment over the past two decades in terms of a gradually rising European NAIRU, our analysis suggests that the gradual tightening of monetary policy over this period may have played a significant role (alongside other demand- and supply-side factors).

Our analysis does not imply, however, that monetary policy should be devoted to fine-tuning real macroeconomic activity. On the contrary, since it can take a long time for the influence of monetary policy to work itself out - and thus a long time to bring inflation under control, as we have witnessed through the 1980s and early 1990s - it is important to keep monetary policy anchored around long-run inflation objectives. What our analysis does imply is that permanent changes in monetary policy have long-lasting real effects, and thus monetary policy cannot be conducted without regard to these effects.

Finally, our analysis also implies that the NAIRU should be removed from the tool kit of monetary policy makers. Our empirical investigation indicates that there exists no NAIRU, such that inflation rises without limit when unemployment is below the NAIRU and falls without limit when unemployment is above it. The NAIRU is conventionally understood as depending only on real phenomena (such as the generosity of unemployment benefits, degree of imperfect information and imperfect competition), whereas our analysis shows the long-run unemployment rate to depend on money growth (viz., its underlying monetary policy instruments). Thus the challenge of monetary policy is not to keep unemployment close to the NAIRU at moderate inflation rates, but to keep inflation under control in a world in which monetary policy has long-lived repercussions on real macroeconomic activity.

## References


[1] Ascari, G. (2000), "Optimising Agents, Staggered Wages and the Persistence of the Real Effects of Money Shocks," *Economic Journal*, 110, 665-686.

[2] Ascari, G. (2001), "Price-Wage Staggering and Persistence: A Unifying Framework," *mimeo.*

[3] Ascari, G. and N. Rankin (2002): "Staggered Wages and Output Dynamics under Disinflation", *Journal of Economic Dynamics and Control*, No. 26, 653-680.

[4] Baltagi, B. H. (1995): *Econometric Analysis of Panel Data*, New York: Wiley.

[5] Baltagi, B. H. and J. M. Griffin (1997): "Pooled estimators vs. their heterogeneous counterparts in the context of dynamic demand for gasoline", *Journal of Econometrics*, No. 77, 303-327.

[6] Baltagi, B. H. and C. Kao (2000): "Nonstationary Panels, Cointegration in Panels and Dynamic Panels: A Survey", mimeo.

[7] Banerjee A. (1999): "Panel Data Unit Roots and Cointegration: An Overview", *Oxford Bulletin of Economics and Statistics,* special issue, 607-629.

[8] Bårdsen, G., E. Jansen and R. Nymoen (2002): "The Empirical (Ir)relevance of the New Keynesian Phillips Curve," Norwegian University of Science and Technology, Working Paper Series No. 21/2002.

[9] Bernanke, B., M. Gertler and S. Gilchrist (2000): "The Financial Accelerator in a Quantitative Business Cycle Framework," in John Taylor and Michael Woodford, eds., *Handbook of Macroeconomics*, Amsterdam: North Holland, 2000, chapter 21.

[10] Blanchard, O. and S. Fischer (1989): *Lectures in Macroeconomics*, Cambridge, Massachusetts: MIT Press.

[11] Calvo, G.A. (1983): "Staggered Prices in a Utility-Maximizing Framework", *Journal of Monetary Economics*, 12, 383-398.

[12] Chari, V.V, P.J. Kehoe and E.R. McGrattan (2000), "Sticky Prices Models of the Business Cycle: Can the Contract Multiplier Solve the Persistence Problem?" *Econometrica*, 68(5), 1151-1180.

[13] Clarida, R., J. Galí and M. Gertler (1999): "The Science of Monetary Policy: A New Keynesian Perspective," *Journal of Economic Literature*, 37, December, 1661-1707.

[14] Fisher, R. A. (1932): *Statistical Methods for Research Workers,* Edinbutgh: Oliver & Boyd.

[15] Friedman, M. (1968): "The Role of Monetary Policy", *American Economic Review*, 58, March, 1-17.

[16] Galí, J. and M. Gertler (1999), "Inflation Dynamics: A Structural Econometric Analysis," *Journal of Monetary Economics*, 44, 195-222.

[17] Galí, J., M. Gertler and D. López-Salido (2001): "European inflation dynamics", *European Economic Review*, 45, 1237-1270.

[18] Galí, J. (2003): "New Perspectives on Monetary Policy, Inflation and the Business Cycle," forthcoming in *Advances in Economics and Econometrics*, edited by M. Dewatripont, L. Hansen, and S. Turnovsky, Cambridge: Cambridge University Press.

[19] Goodfriend, M. and R. G. King (1997), "The New Neoclassical Synthesis and the Role of Monetary Policy," *NBER Macroeconomics Annual*, Cambridge, Mass: MIT Press, 231-295.

[20] Graham, L. and D. J. Snower (2002): "The Return of the Long-Run Phillips Curve," *CEPR Discussion Paper No. 3691*, London *IZA Discussion Paper No. 646*, Bonn.

[21] Gordon, R. (1982), "Inflation, Flexible Exchange Rates, and the Natural Rate of Unemployment," in *Workers, Jobs and Inflation*, ed. by Martin N. Baily, Washington, D.C.: Brookings, 88-152.

[22] Harris, R. D. F. and E. Tzavalis (1999): "Inference for Unit Roots in Dynamic Panels where the Time Dimension is Fixed", *Journal of Econometrics*, 91, 201-226.

[23] Helpman, E., and L. Leiderman (1990), "Real Wages, Monetary Accommodation, and Inflation," *European Economic Review*, 34, 897-911.

[24] Hsiao, C. (1986): *Analysis of Panel Data*, Cambridge: Cambridge University Press.

[25] Huang, K. X.D. and Z. Liu (2002): "Staggered Price-Setting, Staggered Wage Setting, and Business Cycle Persistence," *Journal of Monetary Economics*, 49, 405-433.

[26] Im, K. S., M. H. Pesaran and Y. Shin (2003): "Testing for Unit Roots in Heterogeneous Panels", *Journal of Econometrics*, 115, 53-74.

[27] Karanassou, M., H. Sala and D.J. Snower (2002): "A Reappraisal of the Inflation-Unemployment Trade-off", *IZA Discussion paper No 636*, Bonn.

[28] Kiviet, J. F. (1995): "On bias, inconsistency, and efficiency of various estimators in dynamic panel data models", *Journal of Econometrics*, 68, 53-78.

[29] Levin, A. and C. F. Lin (1993): "Unit Root Tests in Panel Data: New Results", Department of Economics, University of California at San Diego, *Discussion Paper No. 93-56.*

[30] Levin, A., C. F. Lin and C. S. J. Chu (2002): "Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties", *Journal of Econometrics*, 108, 1-24.

[31] Lindbeck, A. and D.J. Snower (1994): "How are product demand changes transmitted to the labour market?", *The Economic Journal*, 104, March, 386-398.

[32] Lindbeck, A., and D.J. Snower (1999), "Price Dynamics and Production Lags," *American Economic Review*, 89 (2), 81-88.

[33] Lindé, J. (2002), "Estimating New-Keynesian Phillips Curves: A Full Information Maximum Likelihood Approach", *Sveriges Riksbank Working Paper Series No. 129.*

[34] Maddala, G. S. and S. Wu (1999): "A comparative Study of Unit Root Tests with Panel Data and a New Simple Test", *Oxford Bulletin of Economics and Statistics,* special issue, 631-652.

[35] Mankiw, N. G. (2001): "The Inexorable and Mysterious Tradeoff between Inflation and Unemployment", *The Economic Journal*, 111, May, C45-C61.

[36] Phelps, E.S. (1967), "Phillips Curves, Expectations of Inflation and Optimal Unemployment over Time," *Economica*, 34, August.

[37] Phillips, P. C. B. and H. R. Moon (1999): "Linear Regression Limit Theory for Nonstationary Panel Data", *Econometrica,* Vol. 67, No. 5, 1057-1111.

[38] Rudd, J. and K. Whelan (2001): "New Tests of the New-Keynesian Phillips Curve", Federal Reserve Board, *Working Paper No. 2001-30.*

[39] Staiger, D. and J. Stock (1997): "Instrumental variables regression with weak instruments", *Econometrica*, 65 (3), pp. 577-586.

[40] Smith, R. P. (2000): "Estimation and inference with non-stationary panel time-series data", *mimeo.*

[41] Taylor, John B. (1979), "Staggered Wage Setting in a Macro Model," *American Economic Review*, 69, May, 108-113.

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