NBER WORKING PAPER SERIES

HYSTERESIS AND THE EUROPEAN UNEMPLOYMENT PROBLEM REVISITED

Jordi Galí

Working Paper 21430
http://www.nber.org/papers/w21430

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
July 2015

Prepared for the ECB Forum on Central Banking held at Sintra, 21-23 May, 2015. I thank Cristina Manea for excellent research assistance, and Samuel Skoda for help with euro area data. I am grateful for comments and suggestions to an anonymous referee, Davide Debortoli, Bob Gordon, Gernot Muller, Athanasios Orphanides, and seminar and conference participants at CREI-UPF, Sintra and the Sveriges Riksbank. The views expressed herein are those of the author and do not necessarily reflect the views of the National Bureau of Economic Research.

The author has disclosed a financial relationship of potential relevance for this research. Further information is available online at http://www.nber.org/papers/w21430.ack

Hysteresis and the European Unemployment Problem Revisited
Jordi Galí
NBER Working Paper No. 21430
July 2015
JEL No. E24,E31,E32

ABSTRACT

The unemployment rate in the euro area appears to contain a significant nonstationary component, suggesting that some shocks have permanent effects on that variable. I explore possible sources of this nonstationarity through the lens of a New Keynesian model with unemployment, and assess their empirical relevance.

Jordi Galí
Centre de Recerca en Economia Internacional (CREI)
Ramon Trias Fargas 25
08005 Barcelona
SPAIN
and NBER
jgali@crei.cat

1 Introduction

The existence of significant differences in the behavior of U.S. and European unemployment has been long recognized, at least since Blanchard and Summer's influential *hysteresis* paper.[1] Such differences are apparent in Figure 1, which displays quarterly time series for the unemployment rate in those two economies, spanning the period 1970Q1-2014Q4, and with the (current) euro area taken to represent Europe (here and throughout the paper). The U.S. unemployment rate shows substantial cyclical volatility, but with a clear tendency to revert back to some (nearly constant) resting point. By contrast, the unemployment rate in the euro area wanders about a (seemingly) upward trend, showing variations that are both smoother and more persistent than its U.S. counterpart. Each recession episode appears to pull the euro area unemployment rate towards a new, higher plateau, from which it eventually drifts away as the economy recovers, but without any apparent tendency to gravitate towards some constant long-run equilibrium value.

In the language of time series analysis, the behavior of the U.S. unemployment rate seems consistent with a *stationary* stochastic process, while in the euro area the same variable displays fluctuations characteristic of a stochastic process with a *unit root*, i.e. a nonstationary process with a random walk-like permanent component.

In the present paper I take seriously the hypothesis of a unit root in euro area unemployment and explore some of its possible causes.[2]

[1] Blanchard and Summers (1986). See Ball (2008) for a recent analysis of potential hysteresis in unemployment in a large number of OECD countries.

[2] See below for some caveats on a literal interpretation of the unit root property in the unemployment rate.

The presence of a unit root in the unemployment rate implies the existence of at least one type of economic disturbance that has a permanent effect on that variable. In the analysis below I seek to uncover *possible sources of that unit root*, and assess their *empirical plausibility*, using as a reference framework a New Keynesian model with unemployment, as developed in Galí (2011a,b) and Galí, Smets and Wouters (2012).

Below I put forward three (non mutually exclusive) hypotheses on the source of the unit root in unemployment, which I refer to as the *natural rate hypothesis*, the *long-run tradeoff hypothesis* and the *hysteresis hypothesis*. The analysis in the paper suggests that none of the three hypothesis can, by itself, account for the evidence on unemployment and wage inflation for the period 1970-2014, though both the long run tradeoff hypothesis and hysteresis hypothesis can help interpret certain aspects of the joint behavior of the unemployment rate and wage inflation. In particular, the long run tradeoff hypothesis could in principle account for the secular rise in unemployment in the 1970s and 1980s as a consequence of the disinflation experienced over that period, though the large decline in the unemployment rate is hard to rationalize. The hysteresis hypothesis, on the other hand, can potentially account for the remarkable stability of wage inflation over the post-1994, despite the persistent nonstationary movements in the unemployment rate.

From a modelling point of view, the present paper can be seen as suggesting alternative approaches to allow for a nonstationary unemployment in a standard macro model. That analysis may prove useful in efforts to incorporate unemployment in DSGE models for the euro area.

The paper is organized as follows. Section 2 contains a first pass at the data, focusing on the seemingly nonstationary behavior of the euro area unemployment rate and its comovement with wage inflation. Section 3 sketches the main elements of the New Keynesian model. Section 4 discusses the three possible sources of a unit root in the unemployment rate through the lens of that model, and discusses their relative empirical relevance in accounting for the euro area evidence. Section 5 summarizes and concludes with a brief discussion of the policy implications.

2 Unemployment and Wages in the Euro Area: A First Look at the Data

2.1 The Unit Root Hypothesis

As discussed in the introduction, even a casual glance at a plot of the unemployment rate in the euro area and the U.S. reveals substantial differences in the behavior of that variable between the two economies (see Figure 1). In particular, the unemployment rate in the U.S. appears to behave like a mean reverting variable, while its euro area counterpart displays a random walk-like pattern.

That visual assessment is confirmed by formal statistical tests. As reported in Table 1, an Augmented Dickey-Fuller (ADF) test of the null of a unit root cannot be rejected for the euro area unemployment rate at conventional significance levels. The opposite result obtains for the U.S., where the null of a unit root is rejected at a 5 percent significance level.[3]

[3]When I restrict the sample period to the single monetary policy one (1999Q1-2014Q4) I cannot reject the null of a unit root in either the euro area or the U.S. unemployment rate. The latter finding may reflect the well known low power of unit root tests in small samples.

The different persistence properties of the two variables are also reflected in their estimated autocorrelations, shown in Figure 2. The one for the U.S. unemployment rate declines rapidly as the lag order increases, whereas the corresponding autocorrelation for the euro area remains close to unity even at relatively high lags, showing the very slow decline characteristic of unit root processes.

The previous characterization has potentially dramatic consequences on the long run unemployment gap between the U.S. and the euro area. To illustrate this point, I simulate an out-of-sample path for those variables using two parsimonious statistical models that fit their behavior surprisingly well. In particular, for the U.S. unemployment rate I use the $AR(2)$ process

$$u_t^{US} = \underset{(0.08)}{0.26} + \underset{(0.05)}{1.63} u_{t-1}^{US} - \underset{(0.05)}{0.68} u_{t-2}^{US} + \varepsilon_t^{US}$$

with an estimated standard deviation for the residual of 0.25.

For the euro area, the following $AR(1)$ model for the *first-difference* of the unemployment rate seems to fit the data well

$$\Delta u_t^{EA} = \underset{(0.04)}{0.80} \Delta u_{t-1}^{EA} + \varepsilon_t^{EA} \tag{1}$$

with a residual standard deviation of 0.11.

Figure 3 shows the simulated paths for the unemployment rate in the euro area and the U.S. for the out-of-sample period 2015-2050, as generated by the statistical models above given observed initial conditions at the end of 2014. Note that, in the simulation, the euro area unemployment rate drifts gradually away from its U.S. counterpart, hovering about a 15 percent plateau at the end of the simulation period, while in the U.S. it fluctuates around a value of about 5 percent, as it has done over the past decades. The previous figure illustrates a key difference in the properties of the two models: the fluctuations in the U.S. unemployment rate remain (statistically) bounded around an unchanged mean, though no such "anchor" appears to exist for euro area unemployment.

A first caveat must be raised at this point: a unit root process like (1) cannot describe the behavior of the unemployment rate unconditionally, given that by definition that variable is bounded between 0 and 100 and nothing prevents model (1) to generate unemployment paths that eventually violate those bounds. Thus, a stochastic process with a unit root like (1) should only be taken as a (local) *approximation* to the behavior of unemployment in the euro area during a particular sample period. In other words, one should not interpret (1) as a data generating mechanism that will remain valid independently of the evolution of the unemployment rate.

A second caveat has to do with the power of unit root tests. Whether or not it is possible to uncover a unit root using a finite number of observations spanning a limited period has been the subject of long controversies in the literature.[4] I do not plan to contribute to that debate. Instead, in the remainder of the paper, I take seriously (i.e. as a fact) the presence of a unit root in the euro area unemployment rate in a sense that I find both meaningful and plausible, namely, *that some shocks may have a permanent effect on that variable.* With that premise in mind, I explore the possible sources for that unit root and some of its implications.

[4] See, e.g., Cochrane (1991), Christiano and Eichenbaum (1990).

2.2 Unemployment and Wages: Some Reduced Form Evidence

A central element in the analysis of Blanchard and Summers (1986) was the hypothesis that the high persistence of unemployment in Europe may be due to the nature of its wage setting institutions and the impact of the latter on the sensitivity of wages to unemployment. In particular, one may consider the hypothesis that wages are *insufficiently* responsive to unemployment as a possible explanation for the high persistence of unemployment fluctuations in the euro area.

Next I present some evidence on the joint comovement between wage inflation and the unemployment in the euro area, in the form of pictures and simple regression estimates. That evidence will lay the ground for some of the analysis and discussion in subsequent sections. Characterizing the relation between wage inflation and unemployment, the two variables found in the original Phillips curve (Phillips 1958), thus seems a good first step in the quest for an explanation for the unit root behavior in unemployment. The model in section 3 below also provides a theoretical justification for focusing on those variables.

Figures 4 and 5 provide two perspectives on the evolution of the unemployment rate and wage inflation in the euro area.[5] Figure 4 plots those two variables against time, while Figure 5 displays the same variables against each other on a scatterplot. In both Figures wage inflation is shown in year-on-year terms.

[5] Year-on-year wage inflation is shown in the Figure, for smoothing purposes. Regression estimates are based on quarter-on-quarter wage inflation.

That graphical evidence is supplemented with OLS estimates of the *reduced form* Phillips curve equation.

$$\pi_t^w = \alpha_0 + \alpha_\pi \pi_{t-1}^p + \alpha_u u_t + \varepsilon_t$$

which are reported in Table 2, where π_t^w is (quarter-to-quarter) wage inflation, u_t is the unemployment rate and π_{t-1}^p denotes average price inflation over the past four quarters. The presence of the latter variable is meant to capture the effects on wages of possible indexation to past inflation.[6] All data are drawn from the ECB's *Area Wide Model* (AWM) data set, which I update through the end of 2014.[7]

A number of observations stand out, which I summarize in the form of bullet points.

- As shown in Figure 4, wage inflation shows a marked downward trend over the period 1970-1993. The decline in wage inflation coexists with a substantial rise in the unemployment rate. Wage inflation appears to stabilize after 1993, hovering about a mean of 2.2 percent, in annual terms. The unemployment rate, however, persists in its seemingly nonstationary behavior. The two variables, thus, appear to have decoupled.

- The previous impression is verified by some formal tests. Thus, an ADF test cannot reject the null of a unit root in wage inflation for the full

[6] See Blanchard and Katz (1999) and Galí (2011b) for estimates of a similar specification using U.S. data.

[7] See Fagan, Henry and Mestre (2001). The wage refers to compensation per worker. The inflation variable corresponds to the average growth rate in the harmonized index of consumer prices (HICP) over the past four quarters.

sample period as well as for the 1970Q1-1993Q4 period. However, it is rejected for the post-1993 period. This contrasts with the results of an analogous test applied to the unemployment rate, for which a unit root cannot be rejected in both subsample periods. The previous findings are consistent with the idea of a near-decoupling between wage inflation (which appears well anchored) and the unemployment rate (that keeps behaving in a random walk-like manner). Furthermore, A Phillips-Ouliaris test rejects the null of no cointegration between wage inflation and the unemployment rate (with and without price inflation) for the full sample period, as well as for the 1970Q1-1993Q4 period. Thus the marked (stochastic) trends in wage inflation and the unemployment rate observed in the data before 1993 seem to be related.

- The previous observations are clearly reflected in the wage Phillips curve displayed in Figure 5a, which shows a marked negative slope in the first part of the sample, but appears to flatten out almost completely after 1993. Figure 5b zooms in on the post-1993 subsample period, revealing the persistence of an inverse relation between the two variables, but one that is much weaker than in the pre-1993 period.

- The estimates of the reduced form wage equation, shown in Table 2, capture well some of the previous observations. For the overall 1970-2014 period they point a strong inverse relation between that variable and the unemployment rate. That relation is highly significant, statistically and economically.[8] After 1992, however, the sensitivity to unem-

[8] The presence of unit root in both wage inflation and the unemployment rate should make us view with caution the estimated standard errors, however.

ployment drops considerably, though the relation remains statistically significant. Finally, note that there is evidence of partial indexation to lagged inflation in the first part of the sample period, but not after 1994.

Below I use the previous evidence to assess some of the hypotheses on the sources of the unit root in euro area unemployment.

3 A New Keynesian Model with Unemployment: A Benchmark Specification

In the present section I sketch the main elements of a model that I use as a benchmark in the analysis of section 3 below, where I seek to uncover possible sources of a unit root in the unemployment rate and to assess their plausibility as an explanation of the euro area experience.

The model described next is an extension of the standard New Keynesian (NK). The main difference with respect to the standard NK model lies in the use of a formulation of the household problem which allows for an explicit definition of unemployment, as well as a notion of its natural rate. That formulation of the labor market was originally introduced in Galí (2011a,b) and further developed in Galí, Smets and Wouters (2012).

As discussed below, the benchmark model described in the present section is *in*consistent with the existence of a unit root in the unemployment rate. In a subsequent section I consider three variations on the benchmark model, each of which is, by itself, a potential source of nonstationarity in unemployment.

Next I sketch the main elements of the benchmark model, with special emphasis on the equations describing the labor market. The reader can find a more detailed description, together with derivations, in Galí (2015a).

3.1 Unemployment and the Wage Markup

A key ingredient of the model is the (log) reservation nominal wage $\underline{w}_t$ of the marginal worker employed, which is assumed to be given (in logs) by

$$\underline{w}_t = p_t + c_t + \varphi n_t$$

where p_t is the (log) price level, c_t is (log) consumption, and n_t is (log) employment. Galí (2015a) provides microfoundations for that assumption, based on the optimizing behavior of a representative household.

A second ingredient is the (log) labor force, l_t, which is implicitly determined by

$$w_t = p_t + c_t + \varphi l_t \tag{2}$$

and which can be interpreted as the measure of individuals whose reservation wage is no higher than the current average wage, given the price level and consumption. By definition, those individuals will choose to participate in the labor market–and hence constitute the labor force– though only a subset n_t of them will be employed.

A third key element of the model is the average wage markup, $\mu_{w,t}$, which is defined as the gap between the average (log) nominal wage and the (log) reservation wage of the average marginal worker:

$$\mu_{w,t} \equiv w_t - \underline{w}_t$$

Finally, the unemployment rate is defined as the (log) difference between the labor force and employment:

$$u_t \equiv l_t - n_t$$

Combining the previous equations one can derive a simple relation between the unemployment rate and the average wage markup, namely

$$\mu_{w,t} = \varphi u_t \tag{3}$$

Figure 6 represents graphically the relationship between the average wage markup and the unemployment rate, using a conventional labor market diagram. The labor supply is given by the participation equation (2). The unemployment rate corresponds to the horizontal gap between the labor supply and labor demand schedules, at the level of the prevailing average real wage. The wage markup $\mu_{w,t}$, on the other hand, is represented in the figure by the gap between the wage and the reservation wage (both expressed in real terms now), at the level of current employment n_t. Given the assumed linearity, the ratio between the two gaps is constant and given by φ, the slope of the labor supply schedule, as implied by (2).

Both the unemployment rate and the average wage markup are endogenous variables. Their determination is influenced by the wage setting framework in place, among other factors.

3.2 Wage Setting

In the benchmark New Keynesian framework I assume the Calvo-style model of staggered wage setting originally proposed in Erceg, Henderson and Levin (2001) and generally adopted by the literature due to its tractability. In that model only a constant fraction of worker-types (or the unions representing them), drawn randomly from the population, are able to reset their nominal wage in any given period. Under that assumption the evolution of the average (log) nominal wage is described by the difference equation

$$w_t = \theta_w w_{t-1} + (1-\theta_w) w_t^* \tag{4}$$

where θ_w is the fraction of worker-types that keep their wage unchanged, and w_t^* is the newly set (log) wage in period t. The fact that the wage remains unchanged for several periods makes the implied optimal wage setting decision to be forward-looking. In particular, when setting the wage w_t^*, unions take into account the current and future demand for their work services, which is given by:

$$n_{t+k|t} = -\epsilon_{w,t}(w_t^* - w_{t+k}) + n_{t+k} \tag{5}$$

for $k = 1, 2, 3, ...$where $n_{t+k|t}$ denotes period $t+k$ demand for labor whose wage has been reset for the last time in period t, and where $\epsilon_{w,t} > 1$ is the (possibly time varying) wage elasticity of labor demand effective in that period.

When resetting the wage, each union seeks to maximize the utility of the representative household, to which all union members (employed or unemployed) belong. This gives rise to a (log-linearized) wage setting rule of the form:

$$w_t^* = (1-\beta\theta_w)\sum_{k=0}^{\infty}(\beta\theta_w)^k E_t\left\{\mu_{w,t+k}^n + \underline{w}_{t+k|t}\right\} \tag{6}$$

where $\underline{w}_{t+k|t} \equiv p_{t+k} + c_{t+k} + \varphi n_{t+k|t}$ is the relevant reservation wage in $t+k$ for a union that has reset its wage for the last time in period t, and $\mu_{w,t}^n \equiv \log \frac{\epsilon_{w,t}}{\epsilon_{w,t}-1}$ is the *natural wage markup* in period t. It is easy to show that the latter is the wage markup that any union (acting independently) would choose if wages were fully flexible, given a labor demand schedule with an exogenous wage elasticity $\epsilon_{w,t}$.

Combining (4) and (6) (after some algebra) yields the wage inflation equation:

$$\pi_t^w = \beta E_t\{\pi_{t+1}^w\} - \lambda_w(\mu_{w,t} - \mu_{w,t}^n) \tag{7}$$

where $\pi_t^w \equiv w_t - w_{t-1}$ and $\lambda_w \equiv \frac{(1-\theta_w)(1-\beta\theta_w)}{\theta_w(1+\epsilon_w\varphi)}$. The previous equation can in turn be combined with (3) to obtain a New Keynesian Wage Phillips Curve:

$$\pi_t^w = \beta E_t\{\pi_{t+1}^w\} - \lambda_w\varphi(u_t - u_t^n) \tag{8}$$

where

$$u_t^n \equiv \frac{1}{\varphi}\ \mu_{w,t}^n \tag{9}$$

can be thought of as a *natural* rate of unemployment, defined as the rate of unemployment that would prevail in period t if wages were fully flexible (and, hence, the wage markup was given by $\mu_{w,t}^n$).[9]

A particular case of the model above, and a common assumption in the literature, corresponds to that of a constant natural wage markup, i.e. $\mu_{w,t}^n = \mu_w^n$ for all t.[10] In the estimated DSGE model of Smets and Wouters (2003, 2007), on the other hand, $\mu_{w,t}^n$ is allowed to follow a stationary $AR(1)$ process, and shown to be an important source of fluctuations of key macro variables at business cycle frequencies. More generally, and to the extent

[9]In contrast with the original Phillips curve (Phillips (1958)), which involved a static empirical relation between wage inflation and unemployment, (8) is a forward looking relation derived from first principles, with coefficients that are a function of structural parameters. In Galí (2011b), I showed how an extension of (8) allowing for wage indexation to past price inflation and assuming a constant natural rate fits postwar U.S. data surprisingly well.

[10]See, e.g. Erceg, Henderson and Levin (2001).

that $\mu_{w,t}^n$ remains stationary, the same will be true for the natural rate of unemployment, u_t^n.

3.3 Monetary Policy

I specify monetary policy by assuming an interest rate rule of the form:

$$\widehat{i}_t = \phi_i \widehat{i}_{t-1} + (1 - \phi_i)[\phi_\pi (\pi_t^p - \pi^*) + \phi_y \Delta y_t] \tag{10}$$

where $\widehat{i}_t \equiv i_t - (\rho + \pi^*)$ and with π^* denoting the central bank's inflation target.

For values of ϕ_i close to unity (as assumed in the simulations below) the previous rule is similar to the one proposed in Orphanides (2006) and Smets (2010) as a good approximation to ECB policy.

The remaining blocks of the model are standard. Their formal description, as well as the derivation of the relevant equilibrium conditions, can be found in Galí (2015a, chapter 6). I include a brief summary in the appendix, which also contains a description of the calibration used.

3.4 Implications of the Benchmark Model for the Unemployment Rate

Under the (standard) assumption of a stationary natural wage markup $\{\mu_{w,t}^n\}$, the equilibrium of the benchmark model described above can be shown to generate a stationary unemployment rate. This is the case even in technology and demand shocks are permanent.

That result is due to the fact that the gap between the average wage markup and its natural counterpart remains stationary, since the presence of nominal wage rigidities only generates a transitory wedge between the two, given that all wages eventually adjust. As a result, and given (3), the gap between the unemployment rate and its natural counterpart will also be stationary. Since the natural rate of unemployment is stationary under the assumption of a stationary natural wage markup, so will be the unemployment rate.

Accounting for the unit root in the euro area unemployment rate thus requires deviating from some the assumptions of the benchmark model above. The next section discusses three possible such deviations that are capable of generating, by themselves and through independent channels, a nonstationary unemployment rate.

4 Interpreting the Unit Root in Unemployment Through the Lens of the New Keynesian Model: Three Hypotheses

Next I examine the possible sources of a unit root in the unemployment rate through the lens of the New Keynesian model developed above. I consider three hypotheses, which I refer to, respectively, as the *natural rate hypothesis*, the *long run tradeoff hypothesis* and the *hysteresis hypothesis*. Each of these hypotheses is associated with a particular deviation from the assumptions of the benchmark model described in the previous section.

Next I introduce each of the hypotheses, illustrate them by means of some simulations, and discuss their consistency with the empirical evidence.

4.1 The Natural Rate Hypothesis

Under the natural rate hypothesis, the unemployment rate inherits its nonstationarity from the natural rate of unemployment. Nonstationarity in the latter variable is in turn assumed to be inherited from the natural wage markup, given the relation

$$u_t^n \equiv \frac{1}{\varphi}\ \mu_{w,t}^n$$

Note that if we take the model at face value, any permanent change in the natural wage markup must result from a corresponding change (of opposite sign) in the wage elasticity of labor demand $\epsilon_{w,t}$. More generally, it seems reasonable that any exogenous factors of a structural or institutional nature that imply a permanent change in the bargaining power of wage setters would have a similar effect (e.g. a change in firing costs, unemployment benefits, or in the composition of the labor force).

Variations in the natural unemployment rate of this sort are presumably the ones that authors like Gordon (1997) or Staiger, Stock and Watson (1997) have sought to uncover in their efforts to estimate the NAIRU and its changes over time.

Next I analyze the model's predictions regarding the effects of shocks to the natural wage markup under the assumption of a random walk process for that variable (and, hence, for the natural rate of unemployment):

$$\mu_{w,t}^n = \mu_{w,t-1}^n + \varepsilon_t^w$$

I calibrate the standard deviation of ε_t^w so that the standard deviation of the innovations in the random walk component of unemployment generated by the model matches its empirical counterpart. I estimate the latter using a multivariate Beveridge-Nelson decomposition, with the unemployment rate, price inflation, and wage inflation included in the information set. The resulting estimate is 0.45 percent, which given (9) and $\varphi = 5$ implies a standard deviation for ε_t^w of 2.25 percent.[11]

Figure 7 displays the dynamic responses to a one standard deviation (positive) innovation in the natural wage markup based on a calibrated version of the New Keynesian model described above. In response to that shock the unemployment rate raises on impact, and then keeps increasing until it reaches a permanently higher plateau, close to half a percentage point above its initial level. The response of output is, qualitatively, the mirror image to the unemployment response. Wage and price inflation (reported in annualized terms, here and in all subsequent figures) also increase in response to that shock, but their variation seems rather small.[12] Most importantly, however, note that both inflation rates covary positively with the unemployment rate.

4.1.1 Empirical Assessment

To what extent can the unit root in euro area unemployment be viewed as the result of exogenous permanent changes in the natural rate? It should be clear that a proper answer to that question should be based on the analysis of an estimated model with a richer specification to the one considered here. That analysis is beyond the scope of the present paper. Yet, a first assessment can

[11] Note that the stationarity of the unemployment gap, combined with equation (**??**) implies that $\sigma(\varepsilon_t^w) = \varphi\sigma(u_t^{BN})$. Given the baseline setting $\varphi = 5$, it follows that $\sigma(\varepsilon_t^w) = 5(0.0045) = 0.0225$.

[12] Note that the reason why wage inflation increases is that the unemployment rate does not increase as much as its natural counterpart in the wake of a shock to the latter. In other words, the average wage markup remains persistently below its desired counterpart, leading workers/unions adjusting their wages to raise the latter, thus generating the observed positive response of wage inflation.

be made by contrasting with the data some of the predictions of the above framework under the null hypothesis that the unit root in unemployment is caused by a unit root in its natural rate.

A number of empirical observations appear to be in conflict with that hypothesis. I'll discuss them in turn.

Note first that under the maintained assumption of a random walk process for the natural wage markup, the hypothesis of an exogenous natural rate implies that we can recover the latter as the "permanent" component in a Beveridge-Nelson decomposition of the unemployment rate, while the unemployment gap will correspond to the "transitory" component of the same decomposition. Under the random walk assumption, that correspondence holds independently of the exact specification and calibration of any other aspect of the model, including the sources of fluctuations.

Figure 8 displays the natural rate of unemployment and the unemployment gap, constructed as described above, together with the actual unemployment rate. The shaded areas correspond to euro area recessions, as dated by the CEPR.[13] Note that the amplitude of the fluctuations in the unemployment gap appears quite small relative to the unemployment rate itself. Furthermore, and most importantly, none of the substantial increases experienced by the unemployment rate during the recession episodes since 1970 seem to be driven by increases in the unemployment gap. In fact, the latter is shown to go down during many of the recession episodes. Instead, the bulk of unemployment fluctuations is attributed to exogenous changes in the natural rate itself, with no other disturbances playing a significant role. Such

[13] At the time of writing no call has been made regarding the trough of the last recession, though 2013Q1 has been pointed to as a tentative date.

an interpretation of unemployment fluctuations seems to be clearly at odds with conventional accounts of European business cycle episodes.

The empirical relevance of the natural rate hypothesis can also be assessed by comparing its prediction regarding the evolution of wage inflation with actual wage inflation. Note that (8) can be solved forward to yield:

$$\pi_t^w = -\lambda_w \varphi \sum_{k=0}^{\infty} \beta^k E_t\{\widetilde{u}_{t+k}\}$$

where $\widetilde{u}_t \equiv u_t - u_t^n$ is the unemployment gap, obtained as the cyclical component in the Beveridge-Nelson decomposition of $\{u_t\}$, as discussed above. Given that $\{\widetilde{u}_t\}$ is (by construction) stationary it is clear that the previous model has no chance of accounting for the nonstationary behavior of wage inflation in the pre-1994 period. In order to give the model a better chance, and given the evidence reported in section 2, I use a version of (8) that allows for indexation to past price inflation and which implies:[14]

$$\pi_t^w = \pi_{t-1}^p - \lambda_w \varphi \sum_{k=0}^{\infty} \beta^k E_t\{\widetilde{u}_{t+k}\}$$

In order to estimate the discounted sum $\sum_{k=0}^{\infty} \beta^k E_t\{\widetilde{u}_{t+k}\}$ I follow the approach in Campbell and Shiller (1987), using a VAR for $\mathbf{x}_t \equiv [\widetilde{u}_t, \pi_t^w - \pi_{t-1}^p]$ to forecast future unemployment gaps.[15]

[14] See Galí (2011b) for a derivation and further discussion.

[15] See Galí (2011b) for a discussion. Under the null that the model is correct, one can show

$$\sum_{k=0}^{\infty} \beta^k E\{\widetilde{u}_{t+k} | \mathbf{x}_t, \mathbf{x}_{t-1,\ldots}\} = \sum_{k=0}^{\infty} \beta^k E_t\{\widetilde{u}_{t+k}\}$$

implying that the use of current and lagged values of $\mathbf{x}_t$ as an information set is not restrictive.

Figure 9a displays actual and predicted wage inflation for the full sample period. Predicted wage inflation tracks actual wage inflation reasonably well, especially over the medium and long term. The correlation between the two series is 0.91. But it should be clear that such high correlation is driven by lagged price inflation, combined with the fact that wage and price inflation comove strongly at low frequencies. This is made clear by looking at the component of predicted wage inflation associated with current and expected future unemployment gaps, i.e. $-\lambda_w \varphi \sum_{k=0}^{\infty} \beta^k E_t\{\widetilde{u}_{t+k}\}$, which is also shown in the same figure (labeled as "adjusted"), and which can be seen to play a negligible role in accounting for the overall correlation.

Figure 9b zooms in on the 1999-2014 period, which is characterized by more stable inflation stability and where, as a result, the unemployment gap-related component should in principle play a more central role in accounting for wage inflation fluctuations. But, as the figure makes clear, the natural rate model has a difficult time accounting for such fluctuations. The correlation between actual and predicted wage inflation is now only 0.24, and gets as low as -0.20 when the lagged inflation component is removed.

On the basis of the evidence above, I conclude that exogenous changes in the natural rate are not a plausible explanation for the unit root in euro area unemployment, at least when examined through the lens of the NK model above.

4.2 The Long Run Tradeoff Hypothesis

Under the *long run tradeoff hypothesis*, the unit root in the unemployment rate results from the presence of a unit root in wage inflation, given the long run relation between those two variables implied by the wage Phillips curve (8). The unit root in wage inflation is assumed to be inherited, in turn, from a unit root in the central bank's inflation target. Thus, under the present hypothesis the assumption of a constant inflation target embedded in (10) is relaxed, with the modified interest rate rule being given now by:

$$\widehat{i}_t = \phi_i \widehat{i}_{t-1} + (1-\phi_i)[\phi_\pi(\pi_t^p - \pi_t^*) + \phi_y \Delta y_t]$$

where the central bank's inflation target $\{\pi_t^*\}$ is now assumed to follow an exogenous random walk process

$$\pi_t^* = \pi_{t-1}^* + \varepsilon_t^*$$

and where $\widehat{i}_t \equiv i_t - (\rho + \pi_t^*)$. Permanent changes in the central bank's inflation target eventually lead, in equilibrium, to permanent changes in both price and wage inflation.

On the other hand, the long run relation between the unemployment rate and wage inflation follows from (8) and is given by:[16]

$$u_t = u^n - \frac{1-\beta}{\lambda_w \varphi}\ \pi_t^w$$

The existence of that *long run tradeoff* in the New Keynesian model has a simple explanation: the "engine" of wage inflation in the model is the existence of a discrepancy between the average wage markup and its desired

[16] In the case of *partial* indexation to price inflation that long relation becomes

$$u_t = u^n - \frac{(1-\beta)(1-\gamma)}{\lambda_w \varphi}\ \pi_t^w$$

where $\gamma \in [0,1]$ is the indexation parameter. Note that the long run tradeoff vanishes in the case of full indexation ($\gamma = 1$).

(or natural) counterpart. Accordingly, the only way to attain permanently higher wage inflation is to increase that gap or, equivalently, the gap between the unemployment rate and its natural counterpart, as implied by (8).

Figure 10 displays the model's implied dynamic responses of unemployment, output, wage inflation and price inflation to a permanent reduction of 1 percentage point in the (annualized) inflation target. Note that the disinflation generates a large recession in the short run, with an output decrease of nearly 2 percent and a rise of unemployment of 2.5 percentage points. In the short run, inflation, output and unemployment overshoot their long run level. Most importantly, however, the predicted long run effect on the unemployment rate is very small. This constitutes the main limitation of the long run tradeoff hypothesis, as further discussed below

4.2.1 Empirical Assessment

The long run tradeoff hypothesis seems, at least qualitatively, consistent with the evidence of cointegration between wage inflation and the unemployment rate uncovered above. Figure 11 highlights the existence of that long run relation by plotting the unemployment rate against wage inflation, after changing the sign of the latter. It is clear that cointegration is driven by the comovement between the two variables during the first part of the sample.

The estimated coefficient in a cointegrating regression of the unemployment rate on wage inflation (with the latter expressed in quarterly terms) is -2.04 ($s.e. = 0.09$).[17] If one interprets that empirical relationship as a structural one (in a way consistent with the model), that estimated coefficient

[17] Using the shorter 1970-1993 period yields an identical estimate.

implies a permanent increase of 0.5 percentage points in the unemployment rate for every percentage point of (permanent) reduction in *annualized* inflation. That estimate reflects the large increase in the unemployment rate experienced by the euro area economy during the disinflation between the mid-1970s to the early 1990s.

The unemployment costs of disinflation implied by the estimated cointegrating relation described above are substantially larger than those implied by the model, at least under its baseline calibration. In the latter, the long run increase in the unemployment rate from a permanent reduction in (annualized) inflation of one percentage point is given by $\frac{1-\beta}{4\lambda_w \varphi}$, which under my baseline calibration equals 0.13, which is well below the 0.5 estimate.[18]

The long run tradeoff between unemployment and wage inflation implied by the model can be reconciled with the estimated cointegrating relation (and, hence, with the size of the rise in unemployment that accompanied the disinflation of the 70s-80s) by assuming a lower value for φ. In particular, this is possible if I set $\varphi = 0.08$, implying an Frisch labor supply elasticity of 12.5, well above any estimates found in the literature. Perhaps not surprisingly, a simulation of the model under that alternative calibration and using the innovations in the multivariate Beveridge-Nelson decomposition of wage inflation as a measure of inflation target shocks generates a highly counterfactual standard deviation of 22 percentage points for the unemployment rate, as a result of inflation target shocks only.

Independently of the role that the presence of a long run inflation-unemployment

[18]Note that allowing for indexation to past inflation makes things even worse, for in that case the long run effect on inflation is given by $\frac{(1-\beta)(1-\gamma)}{4\lambda_w \varphi}$ where γ denotes the degree of indexation.

tradeoff effect may have played in accounting for the permanent changes in the unemployment rate in the 1970s and 1980s, it is clear that such a mechanism cannot have played a significant role in accounting for the low frequency movements in the unemployment rate observed in the post-1994 period, for wage inflation has remained highly stable after that date,[19] while the unemployment rate has persisted in its random walk-like behavior, as Figure 11 makes clear.

To summarize: the low frequency comovement between wage inflation and the unemployment rate over the period 1975-1993 seems *qualitatively* consistent with the long run tradeoff hypothesis, which would attribute the permanent variations in the unemployment rate over that period to permanent changes in the inflation target and, in particular, to the (successful) disinflationary monetary policies of that period. Yet, neither the relative magnitude of the changes in the unemployment rate and inflation, nor the subsequent decoupling between those two variables after 1994, can be easily reconciled with that hypothesis, at least through the lens of a conventionally calibrated New Keynesian model.

4.3 The Hysteresis Hypothesis

In their seminal 1986 paper, Blanchard and Summers propose a theory of unemployment that emphasizes insider-outsider considerations in wage setting as an explanation for the high persistence in European unemployment. The basic assumption underlying their theory, closely related to the insider-outsider models of Lindbeck-Snower, Gottfries-Horn and others,[20] is

[19] A unit root in wage inflation is easily rejected in the post-94 period.

[20] See, e.g. Gottfries and Horn (1987) and Lindbeck and Snower (1988).

described in the words of Blanchard and Summers as follows:

> "...there is a fundamental asymmetry in the wage-setting process between insiders who are employed and outsiders who want jobs. Outsiders are disenfranchised and wages are set with a view to ensuring the jobs of insiders. Shocks that lead to reduced employment change the number of insiders and thereby change the subsequent equilibrium wage rate, given rise to hysteresis..."

Here I use a version of the Blanchard-Summers model consistent with the Calvo wage setting formalism, and hence one that can be readily embedded in the New Keynesian model, replacing the standard wage setting condition (6). My assumed wage setting rule is a limiting case of a more general rule in the New Keynesian model with insider-outsider labor markets developed in Galí (2015b).[21] In particular, I assume that unions resetting the wage in period t choose the latter so that, in expectation, only current insiders are employed over the duration of the wage. Current insiders are in turn assumed to correspond to individuals that were employed at the end of the previous period.

Formally, the wage $w_t^*(j)$ for an occupation j that can readjust its wage in period t is set so that the following condition is satisfied:

$$(1-\beta\theta_w)\sum_{k=0}^{\infty}(\beta\theta_w)^k E_t\left\{n_{t+k}(j)\right\} = n_{t-1}(j)$$

The previous assumption, combined with the sequence of labor demand schedules

$$n_{t+k}(j) = -\epsilon_w(w_t^*(j) - w_{t+k}) + n_{t+k}$$

[21] See Galí (2015b) for a detailed derivation and analysis of its monetary policy implications.

for $k=0,1,2,...$implies that the average newly set wage, w_t^*, will be given by:

$$w_t^* = -\frac{1}{\epsilon_w} n_{t-1} + (1-\beta\theta_w) \sum_{k=0}^{\infty} (\beta\theta_w)^k E_t \left\{ w_{t+k} + \frac{1}{\epsilon_w} n_{t+k} \right\} \tag{11}$$

Thus the newly set wage is increasing in current and expected future aggregate wage and employment, for higher values of those variables raise the current and expected future demand for the type of labor provided by the workers/unions currently setting the wage. On the other hand, a high level of employment in the previous period calls for moderate wages in order to preserve the employment status of current insiders.

Rewriting (11) in recursive form and combining the resulting difference equation with (4) yields, after some straightforward algebra, a modified version of the New Keynesian Wage Phillips curve:

$$\pi_t^w = \beta E_t\{\pi_{t+1}^w\} + \lambda_n \Delta n_t \tag{12}$$

where $\lambda_n \equiv \frac{1-\theta_w}{\theta_w \epsilon_w}$.

Note that wage inflation no longer depends on the gap between the unemployment rate and its natural counterpart, but on the *change* in (log) employment. As illustrated below, that feature, when embedded in the full-fledged New Keynesian model generates a unit root in both employment and the unemployment rate: shocks of any nature and persistence –even if purely transitory– that have an initial impact effect on employment, will have a permanent effect on that variable, as well as on output and the unemployment rate. The reason is that unions have a narrow objective when setting wages: maintaining employment at its most recent level (in expectation). Thus, any change in employment resulting from an unanticipated disturbance is bound to become permanent, even after the shock that triggered it has faded away. This is the phenomenon Blanchard and Summers (1986) referred to as "hysteresis".

Under the assumed wage setting arrangement, the relation between the average wage markup and the unemployment rate (3) is still valid. The wage markup (together with unemployment) evolves endogenously in response to any shock, above and beyond the fluctuations associated with wage stickiness. Note that in the present environment, and in contrast with the wage setting model found in the standard New Keynesian model, there is no "anchor" value towards which the wage markup converges after any deviation caused by an exogenous disturbance. As a result, and given (3), there is no mechanism that guarantees that unemployment will revert back towards some constant natural level. Instead, in the wake of an adverse shock, the economy may "stabilize" at a level of employment and output permanently lower, and with a higher unemployment rate.

The previous phenomenon is illustrated in Figure 12, which displays the effects of a *transitory* adverse demand shock in the insider-outsider version of the New Keynesian model. The demand shock is formalized as an exogenous, transitory increase in households' discount rate, which triggers a decline in consumption and, hence, output and employment. The standard deviation of the shock is calibrated for consistency with the observed volatility of the random walk component of the unemployment rate. Note that a one standard deviation shock leads to a permanent increase in unemployment and a commensurate decrease in output. That permanent effect is an illustration of the hysteresis property emphasized by Blanchard and Summers (1986).

Note also that the impact on wage and price inflation is very small.

4.3.1 Empirical Assessment

A key element behind the model's hysteresis property is wage equation (12), which I reproduce here for convenience:

$$\pi_t^w = \beta E_t\{\pi_{t+1}^w\} + \lambda_n \Delta n_t \tag{13}$$

where $\lambda_n \equiv \frac{1-\theta_w}{\theta_w \epsilon_w}$. A feature of the previous equation, namely, the dependence of wage inflation on employment *growth* –as opposed to employment or unemployment *levels*– is the source of hysteresis in the model. Next I try to assess the extent to which an equation like (13) is consistent with the observed joint behavior of employment and wage inflation in the euro area.

To begin with one should note that (13) implies a highly implausible positive long run relation between wage inflation and employment *growth*, which is a very strong form of non-superneutrality. Such a relation is at odds with the lack of evidence of a unit root in Δn_t. Furthermore, a (pseudo) cointegrating regression of Δn_t on π_t^w yields a *negative* estimated coefficient (-0.03), in contrast with the positive one implied by (12), namely $(1-\beta)/\lambda_n$.

The previous counterfactual implication can be overcome through a (standard) modification of the model to incorporate indexation to past inflation between reoptimization periods, as assumed earlier when evaluating the New Keynesian wage Phillips curve under the natural rate hypothesis. I assume a form of indexation which gives rise to the modified wage inflation equation:

$$\widetilde{\pi}_t^w = \beta E_t\{\widetilde{\pi}_{t+1}^w\} + \lambda_n \Delta n_t \tag{14}$$

where $\widetilde{\pi}_t^w \equiv \pi_t^w - \pi_{t-1}^p$

Next I assess the empirical relevance of (14), by constructing its implied prediction of wage inflation, given (current and expected) employment growth, and comparing that prediction with actual wage inflation. Thus, note that (14) implies:

$$\pi_t^w = \pi_{t-1}^p + \lambda_n \sum_{k=0}^{\infty} \beta^k E_t\{\Delta n_{t+k}\}$$

I construct a measure of $\sum_{k=0}^{\infty} \beta^k E_t\{\Delta n_{t+k}\}$ using forecasts of employment growth based on an estimated VAR for $\mathbf{x}_t \equiv [\Delta n_t, \widetilde{\pi}_t^w]$. Again, under the null that the model and calibration are "true," the wage inflation series thus constructed should correspond to its empirical counterpart.[22]

Figure 13a displays the path of wage inflation predicted by the insider-outsider model with and without indexation, together with its observed counterpart. The baseline calibration (which implies $\lambda_n = 0.074$) and in the presence of indexation ("IO model + indexation"). Note that predicted wage inflation in the model with indexation tracks well the medium and long term variations in actual inflation: the correlation between the two series is 0.91. Note, in particular, that the model can account for the substantial stability of wage inflation in the post-1994 period in the face of a persistent random walk-like behavior of the unemployment rate.

Of course, as it was the case for the natural rate model analyzed above, indexation together with the large low frequency variations in inflation in the early part of the sample period are responsible for much of the observed high correlation, as demonstrated by the limited variation of predicted wage inflation in the absence of indexation. Focusing on a more recent period

[22] See, e.g. Campbell and Shiller (1987). Galí (2011b) for an application to wage inflation.

with low and stable inflation and in which indexation is likely to have been less relevant, may provide a better assessment of the model. Figure 13b, shows predicted wage inflation using the insider-outsider model without indexation over the single currency period (1999-2014), together with actual wage inflation. A significant positive comovement between the predicted and actual series is apparent, with a correlation of 0.55. Furthermore, a closer look at Figure 13b suggests that the previous correlation would be significantly higher if it weren't for the model's failure to account for the stubborn stability of wage inflation during the 1998-1999 episode, in the face of a persistent decline in employment. The presence of downward nominal wage rigidities, ignored in the model above, is a potential candidate explanation for the difference.[23]

To conclude the empirical assessment of the wage inflation model implied by the insider-outsider assumption, I compare the path for wage inflation implied by the latter model to that generate by the constant natural rate model, and which in the absence of indexation is given by

$$\pi_t^w = -\varphi \lambda_w \sum_{k=0}^{\infty} \beta^k E_t\{u_{t+k} - u^n\}$$

Again, I focus on the recent single currency period and approximate the natural rate of unemployment by average unemployment over that period (9.4 percent). I use a VAR for $\mathbf{x}_t \equiv [u_t, \pi_t^w]$.to forecast future unemployment rates. Figure 13c displays the implied path for wage inflation generated by

[23] Notice also that the model is predicting correctly the level of wage inflation at the end of 2014, and its seeming stability. According to the model, wage inflation remains relatively stable as a result of two countervailing forces: on the one hand, current and expected employment growth would call for an increase in wage inflation (see "adjusted" series). On the other hand, lower price inflation is helping contain that pressure, through the indexation mechanism.

the insider-outsider and constant natural rate models, under my baseline calibration, alongside with actual wage inflation. As the figure makes clear, the wage inflation fluctuations generated by the constant natural rate model are an order of magnitude larger than those experienced by actual wage inflation or predicted by the insider-outsider model. Thus, I conclude that the wage inflation equation implied by a simple, calibrated New Keynesian model with insider-outsider labor markets fits the observed patterns of employment and wage inflation in the euro area better than the constant natural rate model.

5 Summary and Concluding Remarks

The present paper has offered a preliminary exploration of a phenomenon that has (unfortunately) become a distinctive feature of the European economy, namely, the (seeming) nonstationarity in its unemployment rate. I have sought to uncover some clues about the nature and sources of that nonstationarity by analyzing the joint behavior of unemployment and wage inflation in the euro area, over the period 1970-2014 and trying to interpret it through the lens of a textbook-like New Keynesian model, to which unemployment is incorporated, following the approach in Galí (2011a,b) and Galí, Smets and Wouters (2012).

In particular, I have put forward three alternative hypotheses regarding the unit root in the euro area unemployment rate: the *natural rate hypothesis*, the *long run tradeoff* hypothesis, and the *hysteresis hypothesis*.

My analysis suggests that exogenous permanent variations in the natural rate are unlikely to be behind the unit root in unemployment. The reason is that the behavior of the unemployment gap implied by that hypothesis is hard to reconcile with the observed patterns of wage inflation.

The long run tradeoff hypothesis could in principle account for the secular rise in unemployment in the 1970s and 1980s as a consequence of the disinflation experienced over that period. Yet, the model cannot simultaneously account for the size of the unemployment decline that accompanied the disinflation and the observed volatility of unemployment.

The hysteresis hypothesis, on the other hand, does not appear to be strongly at odds with any aspect of the data. In particular, it can potentially account for the remarkable stability of wage inflation in the face of persistently nonstationary movements in the unemployment rate over the post-1994 period.

It goes without saying that further research is needed, possibly involving a richer, estimated structural model in order to draw more precise conclusions about the sources of the unit root behavior in euro area unemployment. Yet, a number of remarks seem warranted in light of the previous evidence.

Firstly, the low sensitivity of wage inflation (and, by extension, price inflation) to the unemployment rate in the euro area since 1994, uncovered in the estimates above, may have significant implications for the design of monetary policy. On the one hand, it implies that demand-driven fluctuations in the unemployment rate will have small effects on wage inflation and, consequently, on price inflation as well, with smaller second round effects. This may facilitate the attainment of the ECB's price stability objectives. On the other hand it should require a stronger focus on unemployment stabilization, since a policy that were to respond only to significant deviations of inflation from target could imply excessive fluctuations in unemployment and economic activity, given the flatness of the Phillips curve.

Furthermore, if the low sensitivity of inflation to the unemployment rate is due to the presence of hysteresis effects, a case for a greater emphasis on unemployment stabilization can be made, as a formal analysis of optimal monetary policy under hysteresis show.[24] There are two reasons for this. First, in the absence of a countercyclical policy there is no "anchor" that guarantees that unemployment will revert back to some "natural" level. Accordingly, in the absence of a forceful countercyclical policy, the economy may be stuck with an inefficiently low level of activity for a protracted period. Secondly, and in response to shocks that generate a policy tradeoff, any given tightening of monetary policy in response to a deviation from the inflation target would trigger a much larger and persistent increase in the unemployment rate. As a result, the optimal policy is likely to involve a stronger accommodation of inflationary pressures and a greater stability of the unemployment rate than under the labor market environment assumed in the standard New Keynesian model.

[24] See Galí (2015b).

References

Ball, Laurence (2009): "Hysteresis in Unemployment," in J. Fuhrer et al. (eds.) *Understanding Inflation and the Implications for Monetary Policy*, MIT Press (Cambridge, MA).

Blanchard, Olivier and Lawrence Summers (1986): "Hysteresis and the European Unemployment Problem," *NBER Macroeconomics Annual*,

Blanchard, Olivier and Lawrence Katz (1999): "Wage Dynamics: Reconciling Theory and Evidence," *American Economic Review*, Vol. 89, No. 2, pp. 69-74

Campbell, John Y., and Robert J. Shiller (1987): "Cointegration and Tests of Present Value Models," *Journal of Political Economy* 95 (5), 1062-1088.

Erceg, Christopher J., Dale W. Henderson, and Andrew T. Levin (2000): "Optimal Monetary Policy with Staggered Wage and Price Contracts," *Journal of Monetary Economics* vol. 46, no. 2, 281-314.

Fagan, Gabriel, Jérôme Henry, and Ricardo Mestre (2001): "An Area Wide Model for the Euro Area," ECB WP #42.

Galí, Jordi (2011a): *Unemployment Fluctuations and Stabilization Policies: A New Keynesian Perspective*, MIT Press (Cambridge, MA).

Galí, Jordi (2011b): "The Return of the Wage Phillips Curve," *Journal of the European Economic Association*, vol. 9, issue 3, 436-461.

Galí, Jordi (2015a): *Monetary Policy, Inflation and the Business Cycle. An Introduction to the New Keynesian Framework*, Second Edition, Princeton University Press.

Galí, Jordi (2015b): "Monetary Policy Design in a New Keynesian Model with Insider-Outsider Labor Markets," unpublished manuscript.

Galí, Jordi, Frank Smets and Raf Wouters (2012): "Unemployment in an Estimated New Keynesian Model," *NBER Macroeconomics Annual 2011*, 329-360.

Gordon, Robert J. (1997): "The Time-Varying NAIRU and Its Implications for Economic Policy," *Journal of Economic Perspectives* 11(1), 11-32.

Gottfries, Nils and Henrik Horn (1987): "Wage Formation and the Persistence of Unemployment," *Economic Journal* 97(388), 877-884.

Lindbeck, Assar and Dennis J. Snower (1988): *The Insider-Outsider Theory of Employment and Unemployment*, MIT Press (Cambridge, MA).

Nakamura, Emi and Jón Steinsson (2008): "Five Facts about Prices: A Reevaluation of Menu Cost Models," *Quarterly Journal of Economics*, vol. CXXIII, issue 4, 1415-1464.

Orphanides, Athanasios (2006): "Review of the ECB's Strategy and Alternative Approaches," contribution to *The ECB and its Watchers,* Center for Financial Studies, Frankfurt.

Phillips, A.W. (1958): "The Relation between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom, 1861-1957," *Economica* 25, 283-299.

Smets, Frank, and Rafael Wouters (2003): "An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area," *Journal of the European Economic Association*, vol 1, no. 5, 1123-1175.

Smets, Frank, and Rafael Wouters (2007): "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach," *American Economic Review*, vol 97, no. 3, 586-606.

Smets, Frank (2010): "Comment on chapters 6 and 7," in M. Buti et al. (eds.) *The Euro: The First Decade*, Cambridge University Press.

Staiger, Douglas, James H. Stock, and Mark W. Watson (1997): "The NAIRU, Unemployment and Monetary Policy," *Journal of Economic Perspectives* 11(1), 33-49.

Woodford, Michael (2003): *Interest and Prices. Foundations of a Theory of Monetary Policy*, Princeton university Press (Princeton, NJ).

Appendix

Other Blocks

I assume the existence of a continuum of differentiated goods, each produced by a monopolistic competitor, with a production function:

$$Y_t(i) = N_t(i)^{1-\alpha} \tag{15}$$

where $Y_t(i)$ denotes the output of good i, $N_t(i)$ is a CES function of the quantities of the different types of labor services employed by firm i, whose elasticity of substitution is given by $\epsilon_{w,t}$. Cost minimization by firms gives rise to the labor demand schedule (5) introduced above.

Price-setting is assumed to be staggered (à la Calvo), with a constant fraction θ_p of firms that keep prices unchanged. Firms' desired markup in the absence of price rigidities is assumed to be constant and given by $\mu_p \equiv \log \frac{\epsilon_p}{\epsilon_p - 1}$, where ϵ_p is the price elasticity of demand. Aggregation of price-setting decisions, gives rise to a New Keynesian Phillips curve of the form

$$\pi_t^p = \beta E_t\{\pi_{t+1}^p\} - \lambda_p(\mu_{p,t} - \mu_p)$$

where $\mu_{p,t}$ is the average price markup in period t and $\lambda_p \equiv \frac{(1-\theta_p)(1-\beta\theta_p)(1-\alpha)}{\theta_p(1-\alpha+\alpha\epsilon_p)}$.

Equilibrium in the goods market, together with the household's intertemporal optimality condition gives rise to a version of the so called dynamic IS equation:

$$\widetilde{y}_t = E_t\{\widetilde{y}_{t+1}\} - (i_t - E_t\{\pi_{t+1}^p\} - r_t^n) \tag{16}$$

where the output gap, $\widetilde{y}_t \equiv y_t - y_t^n$, is defined as the (log) deviation between output and its natural counterpart, with the latter corresponding to the output level that would prevail in an equilibrium with flexible prices *and* wages. The natural real rate r_t^n is defined in a similar way. The assumptions made (including log consumption utility) imply $y_t^n = a_t - \left(\frac{1-\alpha}{1+\varphi}\right) \mu_{w,t}^n$ and $r_t^n = E_t\{\Delta y_t^n\} + (1-\rho_z) z_t$ for all t, where z_t is a shock to the discount rate (a "demand" shock, henceforth) that follows an exogenous $AR(1)$ process with autoregressive parameter ρ_z. Furthermore, the following relation between the output and markup gaps can be shown to hold:

$$\widetilde{y}_t = -\left(\frac{1-\alpha}{1+\varphi}\right)(\widetilde{\mu}_{w,t} + \widetilde{\mu}_{p,t})$$

where $\widetilde{\mu}_{w,t} \equiv \mu_{w,t} - \mu_{w,t}^n$ and $\widetilde{\mu}_{p,t} \equiv \mu_{p,t} - \mu_p$.

Calibration

Impulse responses and simulations are based on a (rather conventional) calibration of the model's parameter values, which for the most part follows that in Galí (2015a). Thus, I assume $\beta = 0.99$, which implies a steady state real (annualized) return on financial assets of about 4 percent. I also assume $\varphi = 5$ (which implies a Frisch elasticity of labor supply of 0.2), $\alpha = 1/4$, and $\epsilon_p = 9$ (implying $\mathcal{M}_p = 1.125$, i.e., a steady state markup of a 12.5 percent). When relevant, I set $\epsilon_w = 4.5$, a value consistent with an average unemployment rate of 5 percent, roughly the mean unemployment rate in the postwar U.S. economy. I also assume $\theta_p = \theta_w = 3/4$, which impliy an average price and wage durations of four quarters, consistent with much of the empirical evidence. As to the interest rate rule coefficients, I assume $\phi_\pi = 1.5$, $\phi_y = 0.5$, and $\phi_i = 0.9$. That calibration is close to the one proposed in Orphanides (2006) and Smets (2010) as a good approximation to ECB policy.

Table 1. ADF Unit Root Tests

	Euro area		*United States*	
	1 lag	4 lags	1 lag	4 lags
1970Q1-2014Q4	−2.03	−1.91	−3.39**	−2.94**

Note: t-statistics of Augmented Dickey-Fuller tests (with intercept) for the null of a unit root in the unemployment rate. Sample period 1970Q1-2014Q4. Asterisks denote significance at the 5 percent level. Critical value (adjusted for sample size) for the null of a unit root is −2.87.

Table 2. Estimated Reduced Form Wage Equations

	1970Q1-2014Q4		*1970Q1-1993Q4*		*1994Q1-2014Q4*	
u_t	-0.36^{**} (0.018)	-0.20^{**} (0.023)	-0.29^{**} (0.029)	-0.22^{**} (0.034)	-0.06^{**} (0.018)	-0.06^{**} (0.019)
$\pi_{t-1}^{(4)}$		0.74^{**} (0.008)		0.53^{**} (0.111)		0.11 (0.131)
R^2	0.73	0.82	0.58	0.68	0.09	0.09
DW	1.16	1.84	1.62	2.17	2.58	2.61

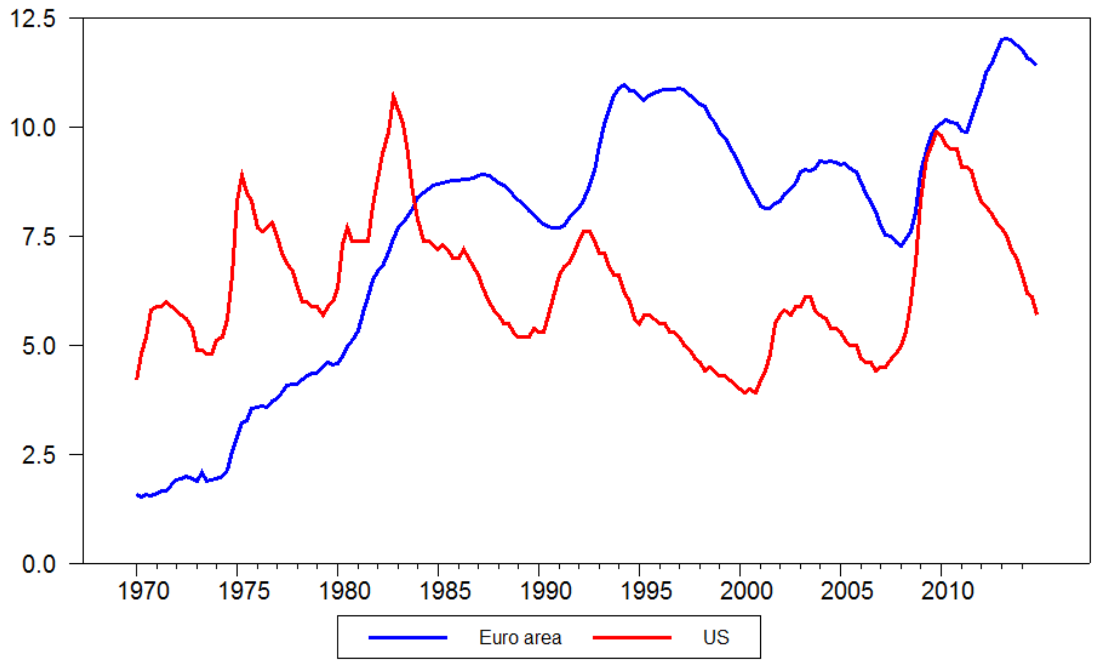

Figure 1. Unemployment Rate: Euro Area vs. United States

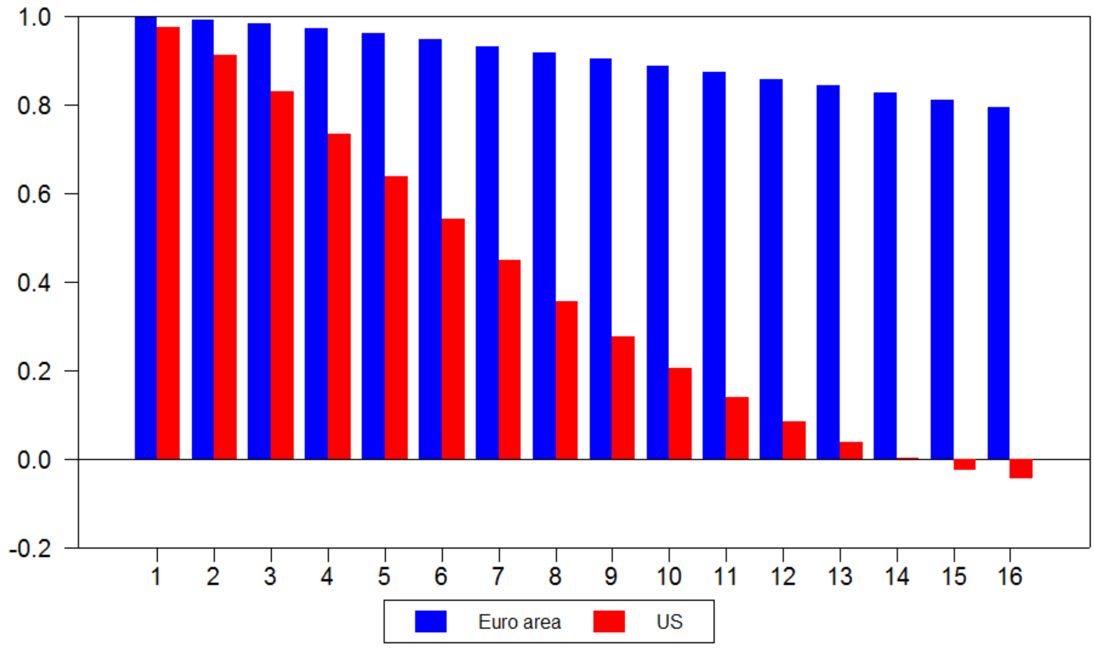

Figure 2. Unemployment Rates: Autocorrelations

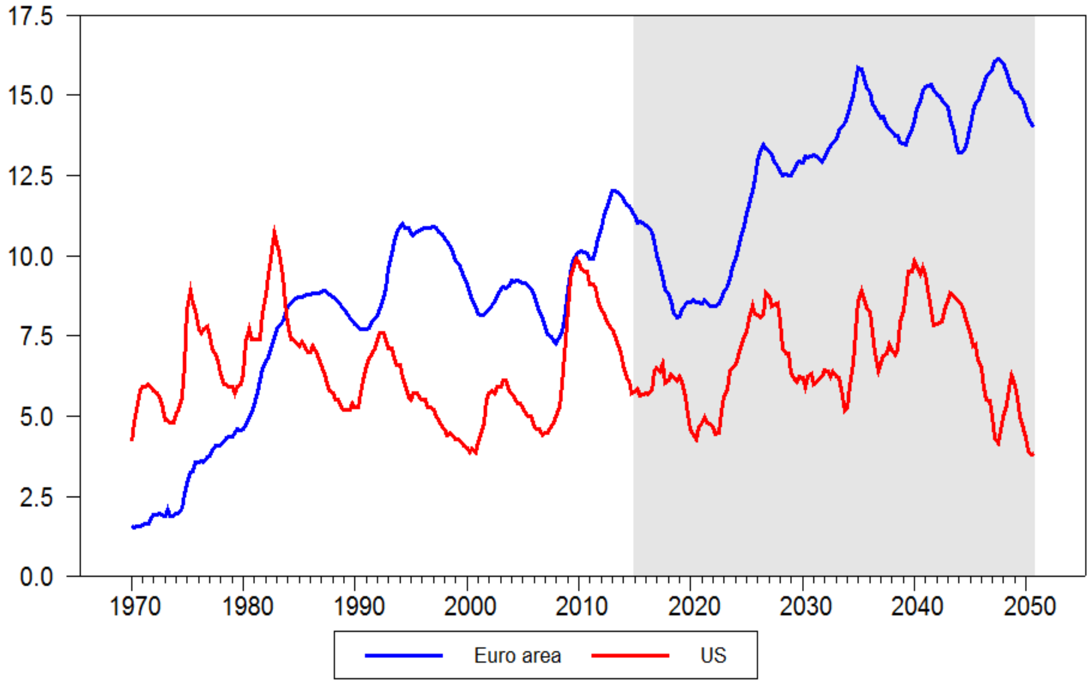

Figure 3. Unemployment Rate: Simulated Paths

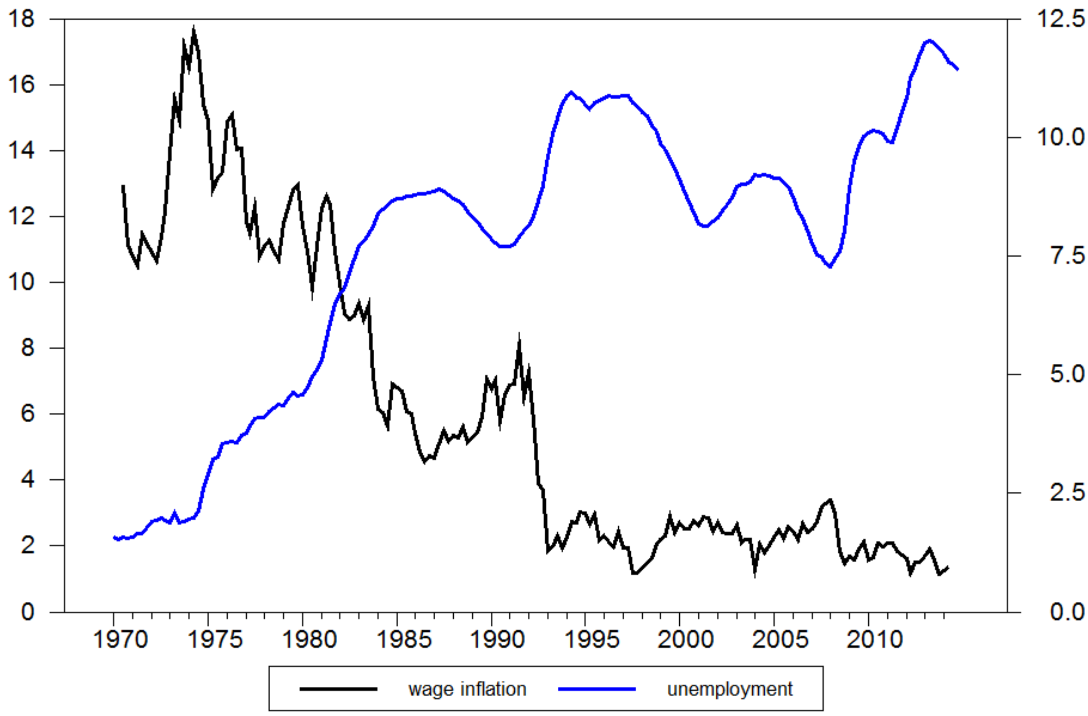

Figure 4. Unemployment and Wage Inflation in the Euro Area

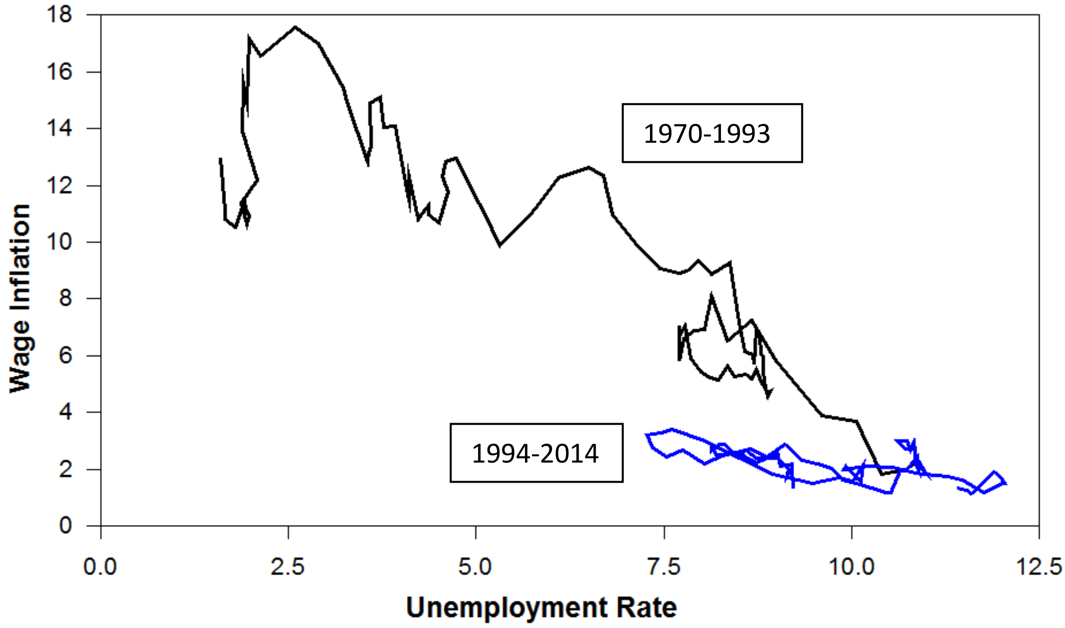

Figure 5a. The Euro Area Wage Phillips Curve (1970-2014)

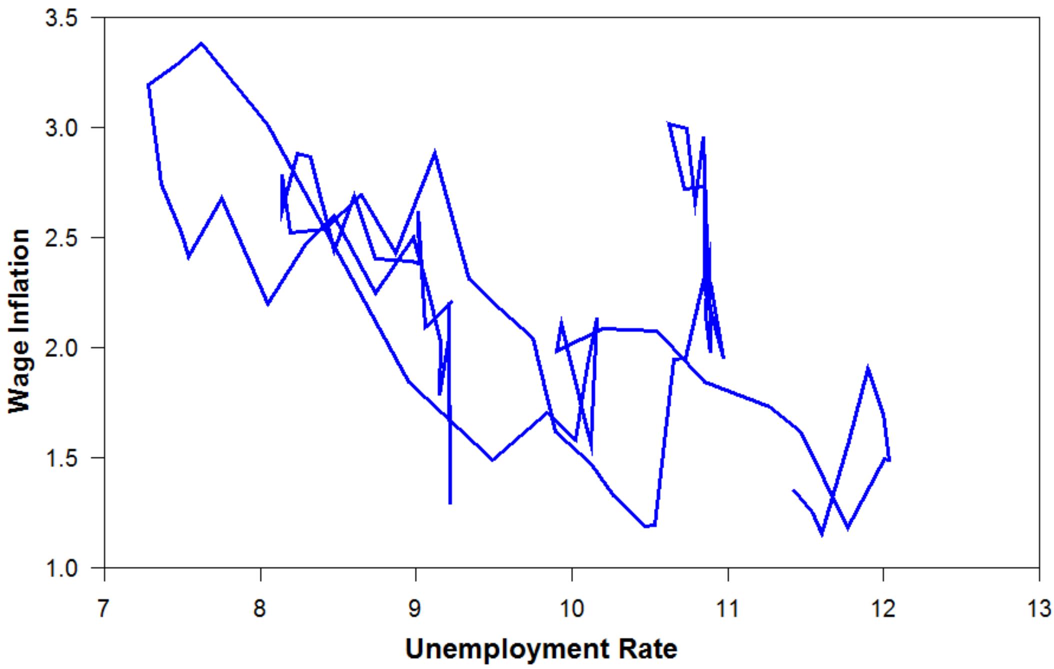

Figure 5b. The Euro Area wage Phillips curve (1994-2014)

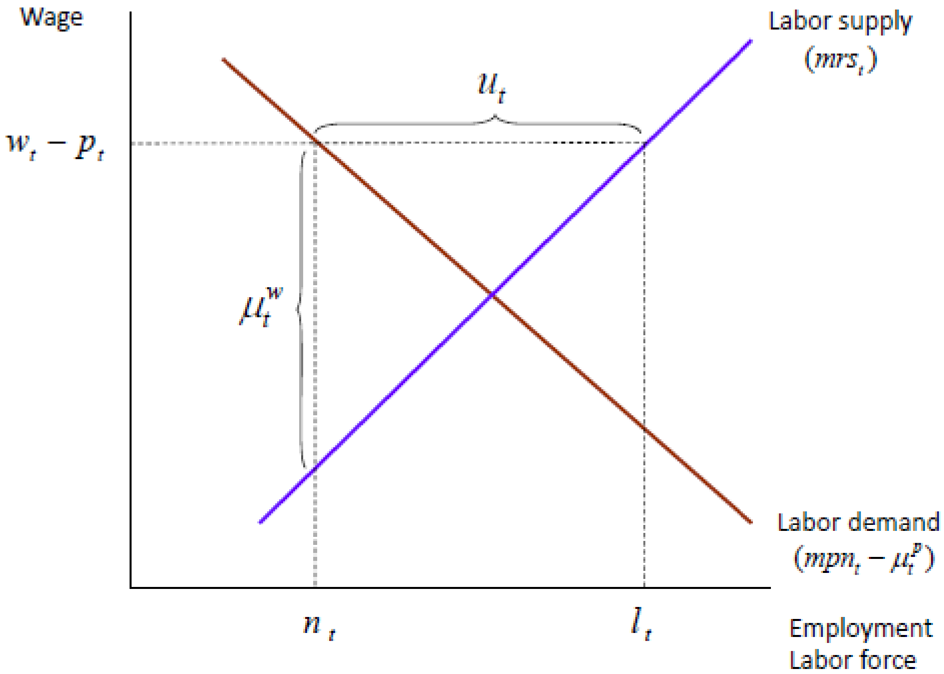

Figure 6. The Wage Markup and the Unemployment Rate

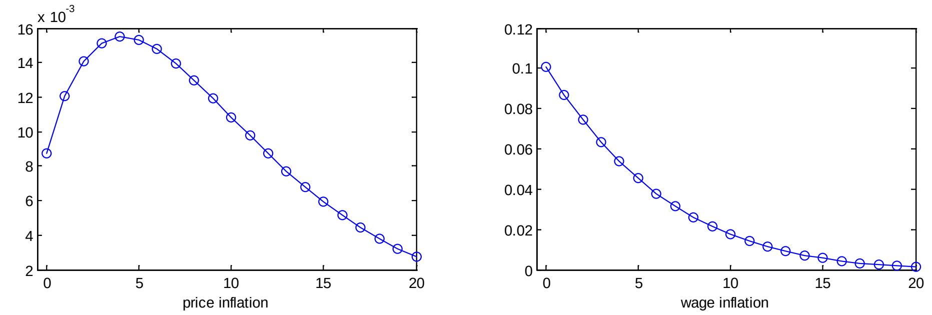

Figure 7. Wage Markup Shock: Dynamic Responses

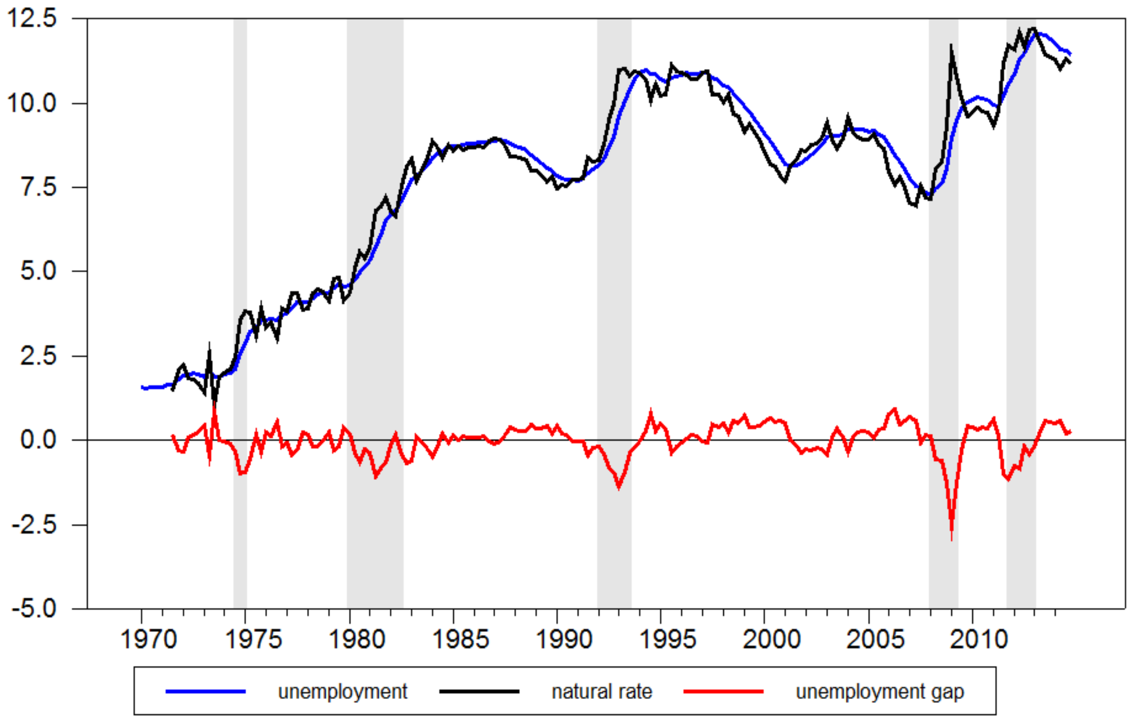

Figure 8. The Natural Rate Hypothesis

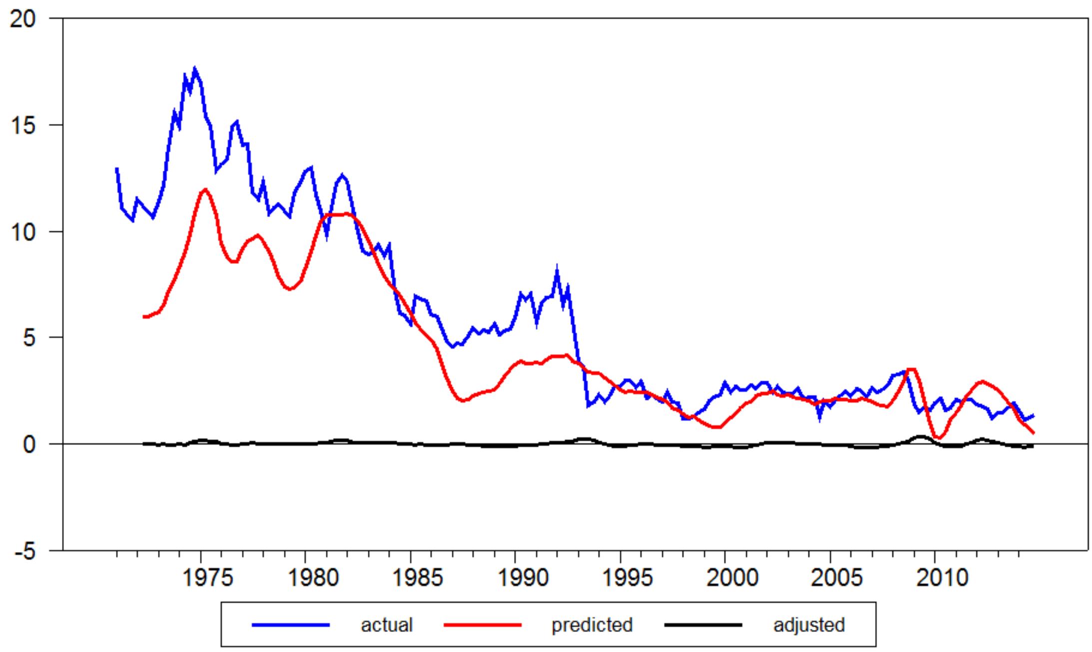

Figure 9a. Wage Inflation under the Natural Rate Hypothesis (1970-2014)

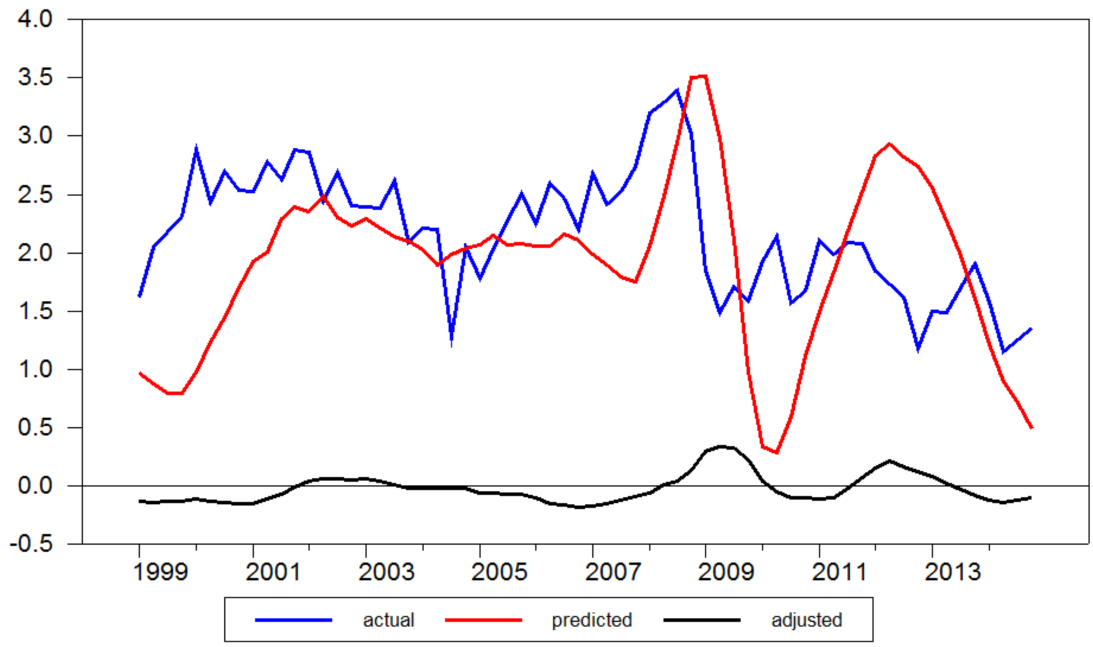

Figure 9b. Wage Inflation under the Natural Rate Hypothesis (1999-2014)

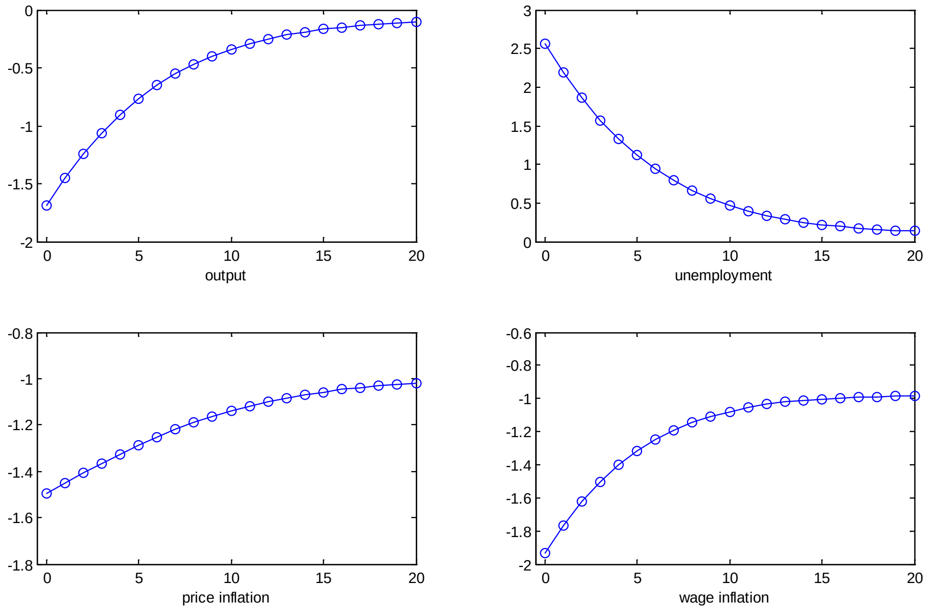

Figure 10. Inflation Target Shock: Dynamic Responses

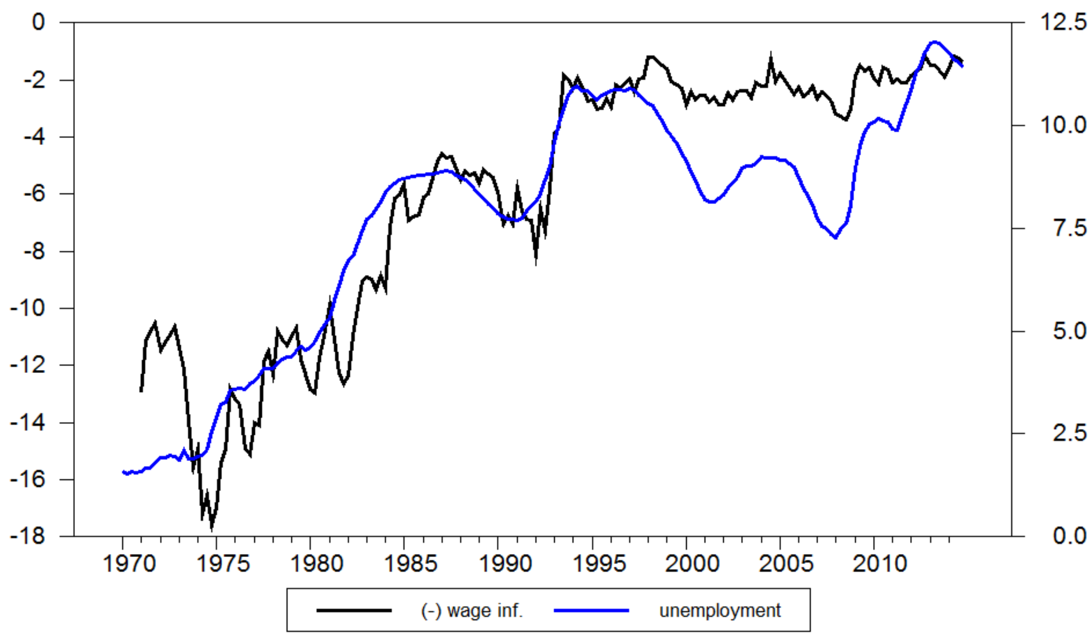

Figure 11. A Long Run Tradeoff Between Inflation and Unemployment?

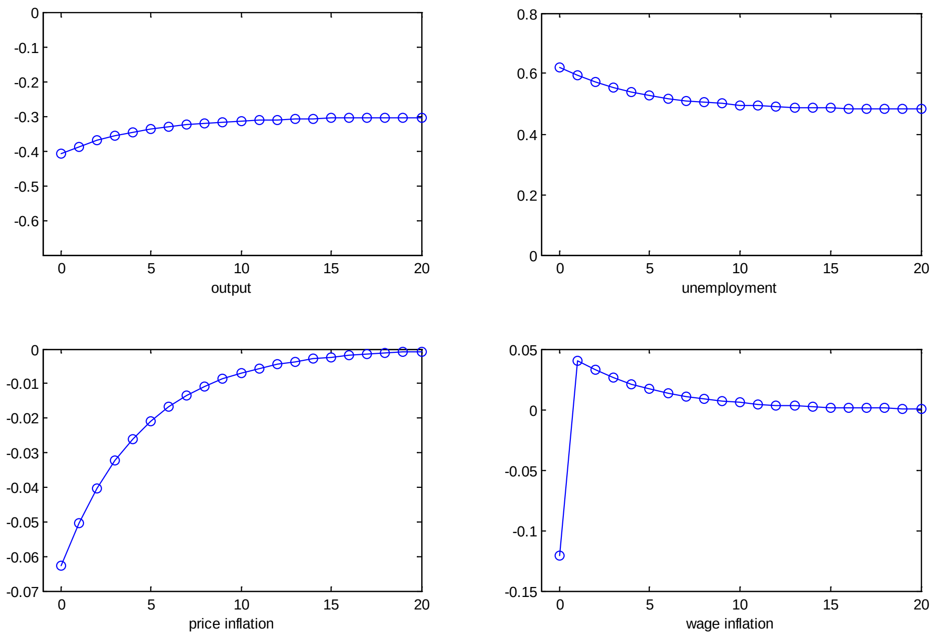

Figure 12. The Insider-Outsider Model: Dynamic Responses to a Demand Shock

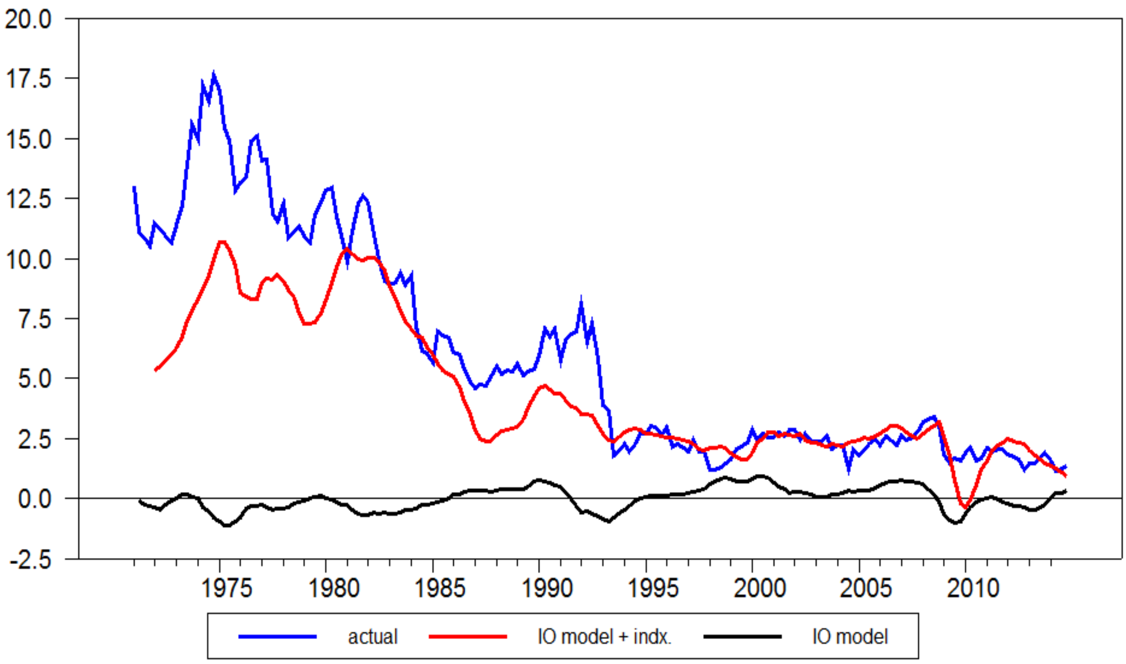

Figure 13a. Wage Inflation in the Insider-Outsider NK Model (1970-2014)

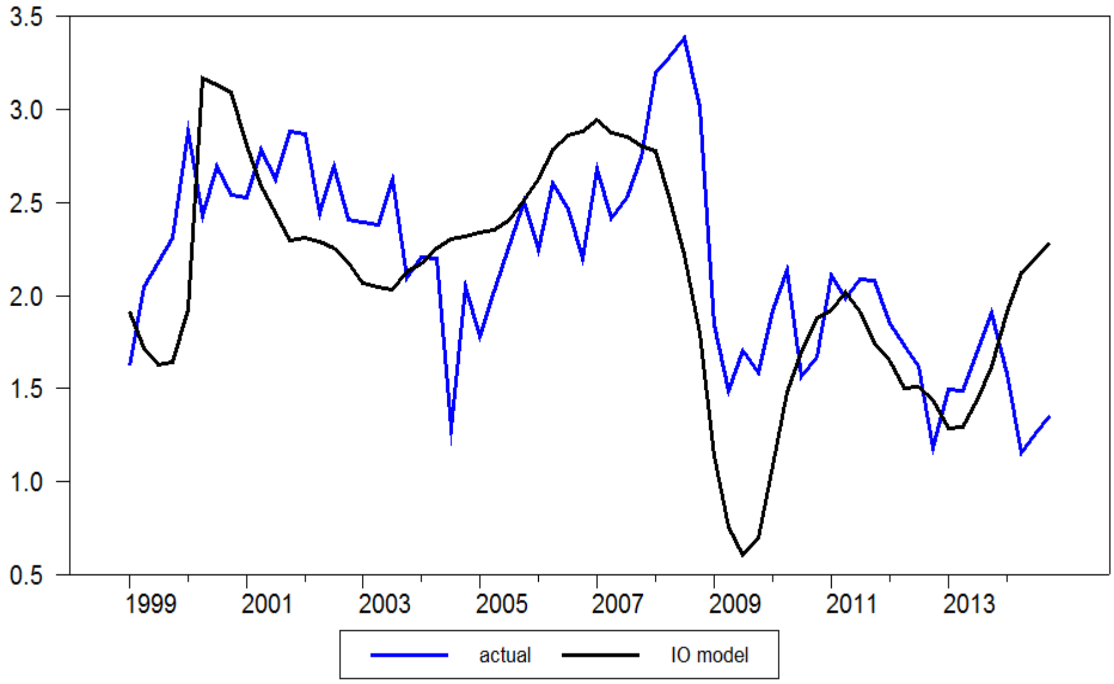

Figure 13b. Wage Inflation in the Insider-Outsider Model (1999-2014)

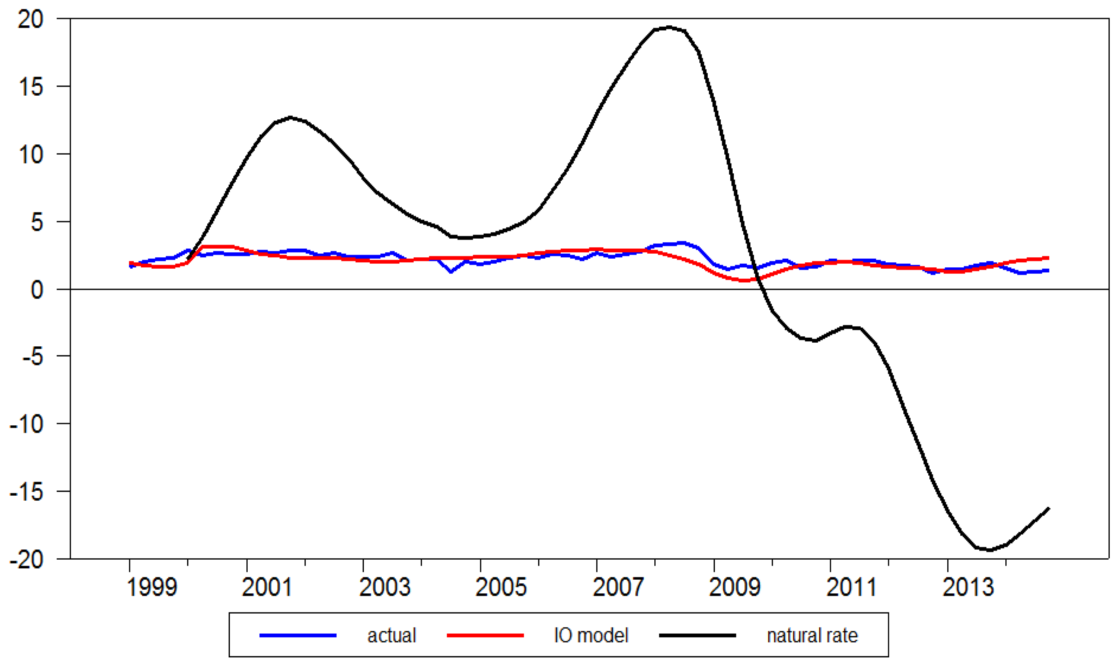

Figure 13c. Wage Inflation: Insider-Outsider vs. Constant Natural Rate Models (1999-2014)