

Hysteresis and the European unemployment problem revisited

By Jordi Galí⁶⁴

Abstract

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

1 Introduction

The existence of significant differences in the behaviour of unemployment in the United States and in Europe has long been recognised, at least since Blanchard and Summers' influential *hysteresis* paper.⁶⁵ Such differences are apparent in Chart 1, which displays quarterly time series for the unemployment rate in those two economies, spanning the period from the first quarter of 1970 to the fourth quarter of 2014, and with the (current) euro area taken to represent Europe (here and throughout the paper). The US 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 US 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 behaviour of the US 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 non-stationary process with a random walk-like permanent component.

In the present paper, I take seriously (i.e. as a fact) the hypothesis of a unit root in euro area unemployment and explore some of its possible causes.⁶⁶

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⁶⁵ Blanchard and Summers (1986). See Ball (2009) for a recent analysis of potential hysteresis in unemployment in a large number of OECD countries.

⁶⁶ 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 and 2011b) 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 trade-off hypothesis* and the *hysteresis hypothesis*. The analysis in the paper suggests that none of the three hypotheses can, by themselves, account for the evidence on unemployment and wage inflation for the period 1970-2014, though both the long-run trade-off hypothesis and hysteresis hypothesis can help interpret certain aspects of the joint behaviour of the unemployment rate and wage inflation. In particular, the long-run trade-off 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 rationalise. The hysteresis hypothesis, on the other hand, can potentially account for the remarkable stability of wage inflation over the post-1994 period, despite the persistent non-stationary 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 non-stationary unemployment rate in a standard macro model. That analysis may prove useful in efforts to incorporate unemployment in dynamic stochastic general equilibrium (DSGE) models for the euro area.

The paper is organised as follows. Section 2 contains a first look at the data, focusing on the seemingly non-stationary behaviour 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 summarises 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 United States reveals substantial differences in the behaviour of that variable between the two economies (see Chart 1). In particular, the unemployment rate in the United States 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 is

obtained for the United States, where the null of a unit root is rejected at a 5% significance level.⁶⁷

Chart 1
Unemployment rate: euro area vs. United States

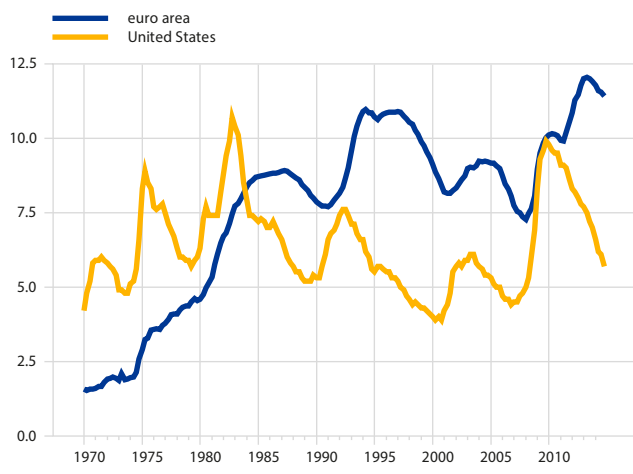
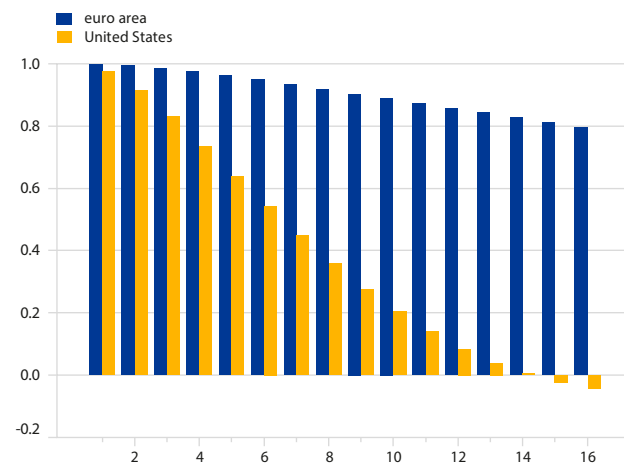


Chart 2
Unemployment rates: autocorrelations



The different persistence properties of the two variables are also reflected in their estimated autocorrelations, shown in Chart 2. The one for the US 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 characterisation has potentially dramatic consequences on the long-run unemployment gap between the United States 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 behaviour surprisingly well. In particular, for the US unemployment rate I use the $AR(2)$ process

$$u_t^{US} = 0.26 + 1.63u_{t-1}^{US} - 0.68u_{t-2}^{US} + \varepsilon_t^{US}$$

(0.08) (0.05) (0.05)

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

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

(0.04)

with a residual standard deviation of 0.11.

⁶⁷ When I restrict the sample period to the single currency period (Q1 1999 – Q4 2014) I cannot reject the null of a unit root in either the euro area or the US unemployment rate. The latter finding may reflect the well-known low power of unit root tests in small samples.

Chart 3

Unemployment rate: simulated paths

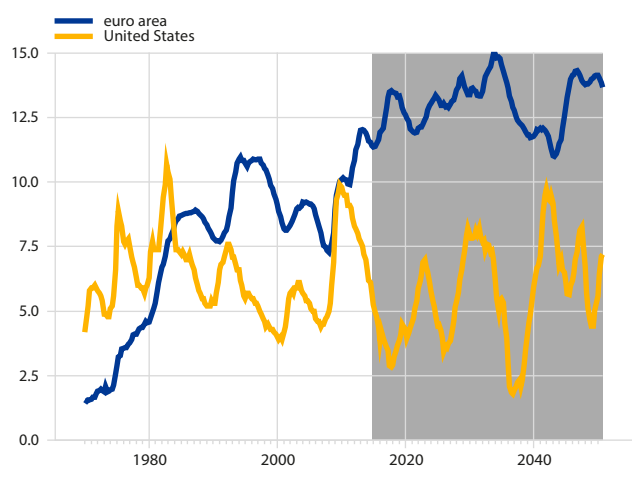


Chart 3 shows the simulated paths for the unemployment rate in the euro area and the United States for the out-of-sample period 2015-2050, as generated by the statistical models above given observed initial conditions at the end of 2014. Note that, in the simulation, the euro area unemployment rate drifts gradually away from its US counterpart, hovering around a 15% plateau at the end of the simulation period, while in the United States it fluctuates around a value of about 5%, 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 US 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 behaviour of the unemployment rate unconditionally, given that by definition that variable is bounded between 0 and 100 and nothing prevents model (1) from generating 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 behaviour 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 long been the subject of controversy in the literature. 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.

2.2

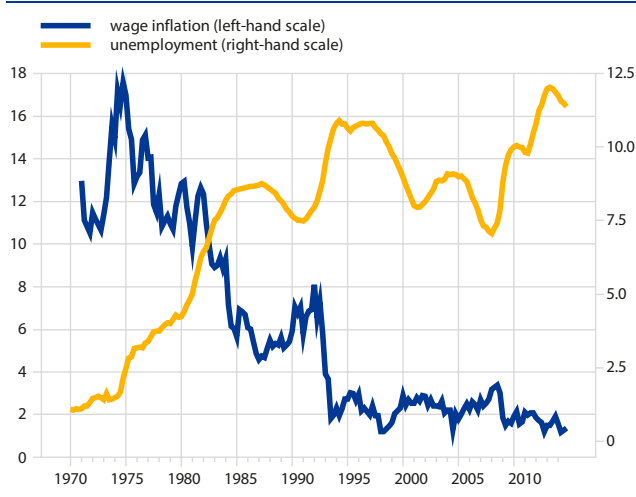
Unemployment and wages: some reduced form evidence

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 of wage inflation and the unemployment rate 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. Characterising the relation between wage inflation and unemployment, the two variables found in the original Phillips curve (Phillips (1958)) thus seem a good first step in the quest for an explanation for the unit root behaviour in unemployment. The model in Section 3 below also provides a theoretical justification for focusing on those variables.

Chart 4
Unemployment and wage inflation in the euro area



Charts 4 and 5 provide two perspectives on the evolution of the unemployment rate and wage inflation in the euro area.⁶⁸ Chart 4 plots those two variables against time, while Charts 5a and 5b display the same variables against each other on a scatterplot (for different sample periods). In both charts wage inflation is shown in year-on-year terms.

That graphical evidence is supplemented with ordinary least squares (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.⁶⁹ All data in this paper are drawn from the *Area-Wide Model* (AWM) dataset detailed in ECB Working Paper No 42 (Fagan, Henry and Mestre (2001)), which I update through to the end of 2014.⁷⁰

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

- As shown in Chart 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 stabilise after 1993, hovering about a mean of 2.2%, in annual terms. The unemployment rate, however, persists in its seemingly non-stationary behaviour. 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 sample period as well as for the Q1 1970-Q4 1993 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

⁶⁸ Year-on-year wage inflation is shown in all charts, for smoothing purposes. Regression estimates are, however, based on quarter-on-quarter wage inflation.

⁶⁹ See Blanchard and Katz (1999) and Galí (2011b) for estimates of a similar specification using US data.

⁷⁰ The wage refers to compensation per worker. The inflation variable corresponds to the average growth rate in the harmonised index of consumer prices (HICP) over the past four quarters.

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 Q1 1970-Q4 1993 period. Thus the marked (stochastic) trends in wage inflation and the unemployment rate observed in the data before 1993 seem to be related.

Chart 5a

The euro area wage Phillips curve (1970-2014)

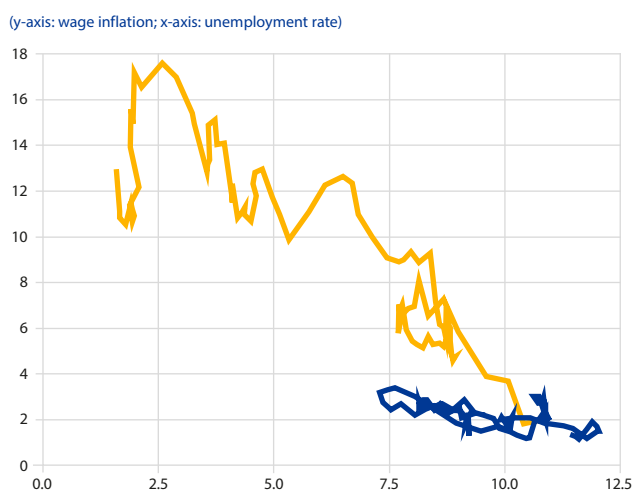
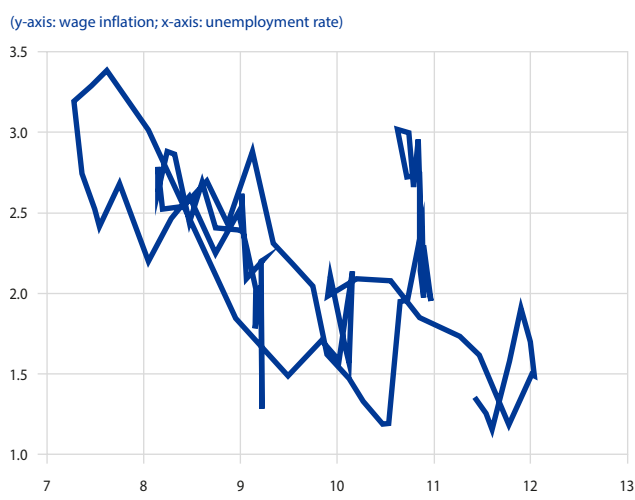


Chart 5b

The euro area wage Phillips curve (1994-2014)



- The previous observations are clearly reflected in the wage Phillips curve displayed in Chart 5a, which shows a marked negative slope in the first part of the sample, but appears to flatten out almost completely after 1993. Chart 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 some of the previous observations well. For the overall 1970-2014 period they point to a strong inverse relation between that variable and the unemployment rate. That relation is highly significant, statistically and economically.⁷¹ After 1992, however, the sensitivity to unemployment 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.

⁷¹ The presence of a unit root in both wage inflation and the unemployment rate should make us view the estimated standard errors with caution, however.

3 A New Keynesian model with unemployment: a benchmark specification

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

The model described is an extension of the standard New Keynesian (NK) model. 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 labour market was originally introduced in Galí (2011a and 2011b) and further developed in Galí, Smets and Wouters (2012).

As discussed below, the benchmark model described in this section is *inconsistent* 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 non-stationarity in unemployment.

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

3.1 Unemployment and the wage mark-up

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 optimising behaviour of a representative household.

A second ingredient is the (log) labour 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 labour market – and hence constitute the labour force – though only a subset of them will be employed.

A third key element of the model is the average wage mark-up, $\mu_{w,t}$, 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 labour 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 mark-up, namely

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

Chart 6
The wage mark-up and the unemployment rate

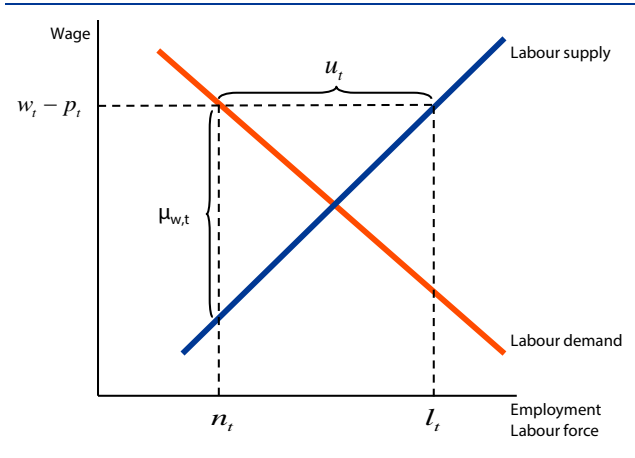


Chart 6 represents graphically the relationship between the average wage mark-up and the unemployment rate, using a conventional labour market diagram. The labour supply is given by the participation equation (2). The unemployment rate corresponds to the horizontal gap between the labour supply and labour demand schedules, at the level of the prevailing average real wage. The wage mark-up $\mu_{w,t}$, on the other hand, is represented in the chart 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 labour supply schedule, as implied by (2).

Both the unemployment rate and the average wage mark-up are endogenous variables. Their determination is influenced by the wage-setting framework in place, among

other factors.

3.2 Wage setting

In the benchmark NK framework I assume the Calvo-style model of staggered wage setting originally proposed in Erceg, Henderson and Levin (2000) and generally adopted by the literature owing 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 $k = 1; 2; 3; \dots$ where $n_{t+k|t}$ denotes period $t+k$ demand for labour 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 labour demand effective in that period.

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

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

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 mark-up* in period t . It is easy to show that the latter is the wage mark-up that any union (acting independently) would choose if wages were fully flexible, given a labour demand schedule with an exogenous wage elasticity $\epsilon_{w,t}$.

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

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

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 (muwu0) to obtain a New Keynesian wage Phillips curve:

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

where

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

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 mark-up was given by $\mu_{w,t}^n$).⁷²

A particular case of the model above, and a common assumption in the literature, corresponds to that of a constant natural wage mark-up, i.e. $\mu_{w,t}^n = \mu_w^n$ for all t .⁷³ In the estimated DSGE model of Smets and Wouters (2003 and 2007), on the other hand, $\mu_{w,t}^n$ is allowed to follow a stationary *AR*(1) process, and is shown to be an important source of fluctuations of key macro variables at business cycle frequencies. More generally, and to the extent that $\mu_{w,t}^n$ remains stationary, the same will be true for the natural rate of unemployment, u_t^n .

⁷² In contrast with the original Phillips curve (Phillips (1958)), which involved a static empirical relation between wage inflation and unemployment, (wpc1) 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 (wpc1) allowing for wage indexation to past price inflation and assuming a constant natural rate fits postwar US data surprisingly well.

⁷³ See, e.g. Erceg, Henderson and Levin (2000).

3.3 Monetary policy

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

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

where $\hat{i}_t \equiv i_t - (\rho + \pi^*)$ 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 mark-up $\{\mu_{w,t}^n\}$, the equilibrium of the benchmark model described above can be shown to generate a stationary unemployment rate. This is the case even if technology and demand shocks are permanent.

That result is due to the fact that the gap between the average wage mark-up 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 $(\mu_{w,t}^n)$, 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 mark-up, 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 non-stationary unemployment rate.

4 Interpreting the unit root in unemployment through the lens of the New Keynesian model: three hypotheses

I examine the possible sources of a unit root in the unemployment rate through the lens of the NK model developed above. I consider three hypotheses, which I refer to, respectively, as the *natural rate hypothesis*, the *long-run trade-off 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 non-stationarity from the natural rate of unemployment. Non-stationarity in the latter variable is in turn assumed to be inherited from the natural wage mark-up, given the relation

$$u_t^n \equiv \frac{1}{\varphi} \mu_{w,t}^n \quad (11)$$

Note that if we take the model at face value, any permanent change in the natural wage mark-up must result from a corresponding change (of opposite sign) in the wage elasticity of labour 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 labour 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 non-accelerating inflation rate of unemployment (NAIRU) and its changes over time.

Next I analyse the model's predictions regarding the effects of shocks to the natural wage mark-up under the assumption of a random walk process for that variable (and, hence, for the natural rate of unemployment): $\mu_{w,t}^n \equiv \mu_{w,t-1}^n + \varepsilon_t^w$

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%, which given (11) and $\varphi = 5$ implies a standard deviation for ε_t^w of 2.25%.⁷⁴

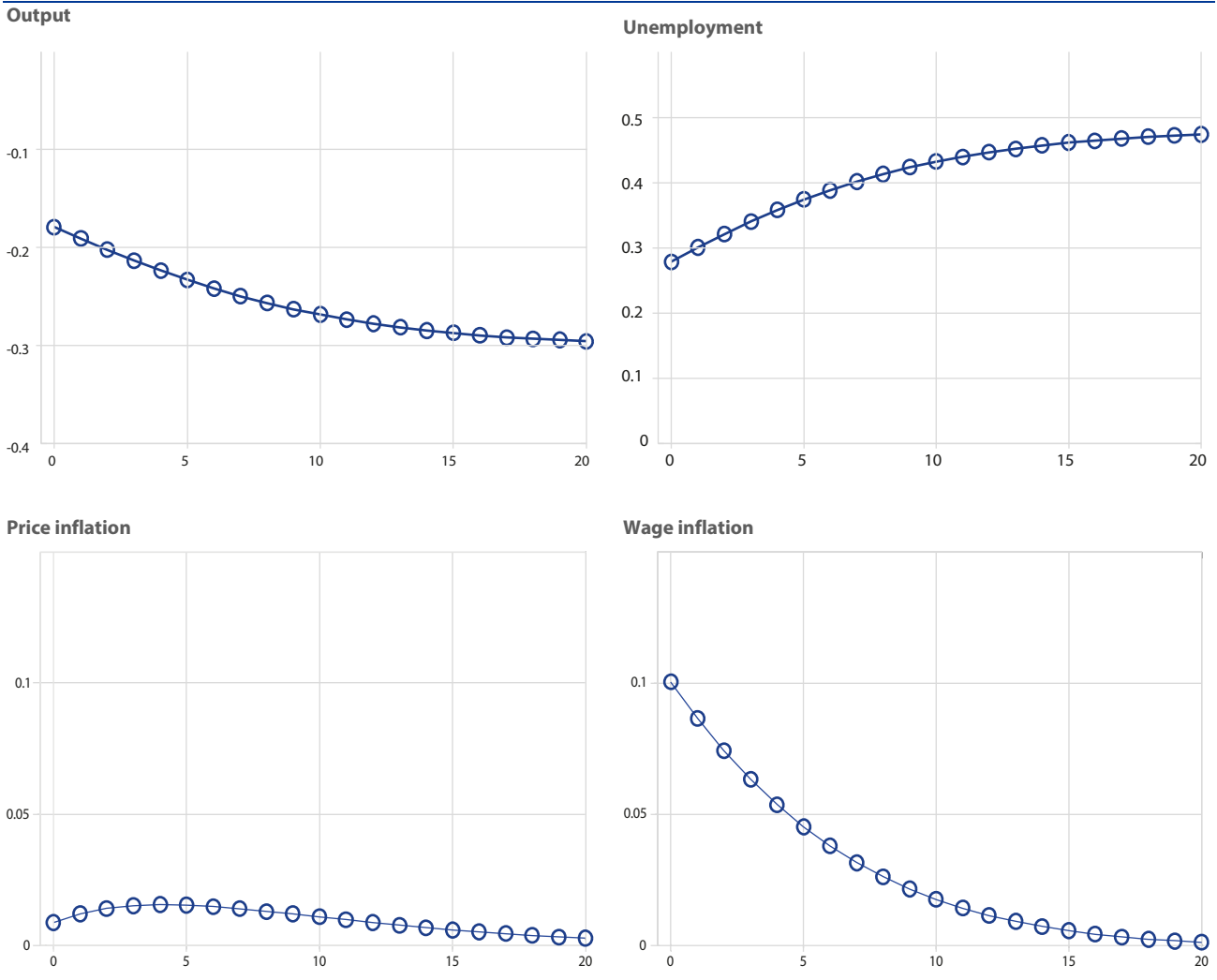
Chart 7 displays the dynamic responses to a one standard deviation (positive) innovation in the natural wage mark-up based on a calibrated version of the NK model described above. In response to that shock the unemployment rate rises on impact and then keeps increasing until it reaches a permanently higher plateau, close to half a percentage point above its initial level. The response of output is, qualitatively, the mirror image of the unemployment response. Wage and price inflation (reported in annualised terms, here and in all subsequent charts) also increase in response to that shock, but their variation

⁷⁴ Note that the stationarity of the unemployment gap, combined with equation (11) implies that $\sigma(\varepsilon_t^w) = \varphi \sigma(u_t^{BN})$. Given the baseline setting $\varphi = 5$, it follows that $\sigma(\varepsilon_t^w) = 5(0.0045) = 0.0225$.

seems rather small.⁷⁵ Most importantly, however, note that both inflation rates covary positively with the unemployment rate.

Chart 7

Wage mark-up shock: dynamic responses



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 than the one considered here. That analysis is beyond the scope of the present paper. Yet, a first assessment can be made by contrasting with the data some of

⁷⁵ 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 mark-up 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.

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 mark-up, 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.

Chart 8
The natural rate hypothesis

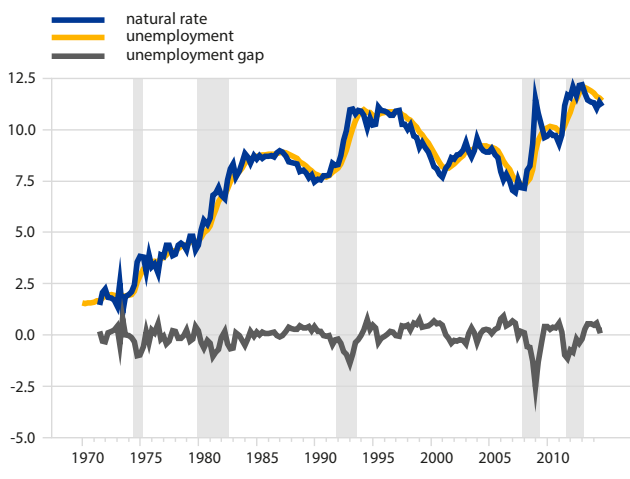


Chart 8 displays the natural rate of unemployment and the unemployment gap, constructed as described above, together with the actual unemployment rate. The shaded areas correspond to euro area recessions, as dated by the CEPR.⁷⁶ Note that the amplitude of the fluctuations in the unemployment gap appears 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 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 (wpc1) can be solved forward to yield: $\pi_t^w = -\lambda_w \varphi \sum_{k=0}^{\infty} \beta^k E_t \{\tilde{u}_{t+k}\}$

where $\tilde{u}_t \equiv u_t - u_t^n$ is the unemployment gap, obtained as the cyclical component in the Beveridge-Nelson decomposition of $\{u_t\}$, as discussed above. Given that $\{\tilde{u}_t\}$ is (by construction) stationary it is clear that the previous model has no chance of accounting for the non-stationary behaviour 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:⁷⁷

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

⁷⁶ Centre for Economic Policy Research. At the time of writing, no call has been made regarding the trough of the last recession, although Q1 2013 has been pointed to as a tentative date.

⁷⁷ See Galí (2011b) for a derivation and further discussion.

In order to estimate the discounted sum $\sum_{k=0}^{\infty} \beta^k E_t \{ \tilde{u}_{t+k} \}$ I follow the approach in Campbell and Shiller (1987), using a vector autoregression (VAR) for $\mathbf{x}_t \equiv [\tilde{u}_t, \pi_t^w - \pi_{t-1}^p]$ to forecast future unemployment gaps.⁷⁸

Chart 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. $-\lambda_w \varphi \sum_{k=0}^{\infty} \beta^k E_t \{ \tilde{u}_{t+k} \}$, which is also shown in the same chart (labelled as “adjusted”), and which can be seen to play a negligible role in accounting for the overall correlation.

Chart 9b zooms in on the 1999-2014 period, which is characterised by more stable inflation 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 chart 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 descends as low as -0.20 when the lagged inflation component is removed.

Chart 9a
Wage inflation under the natural rate hypothesis (1970-2014)

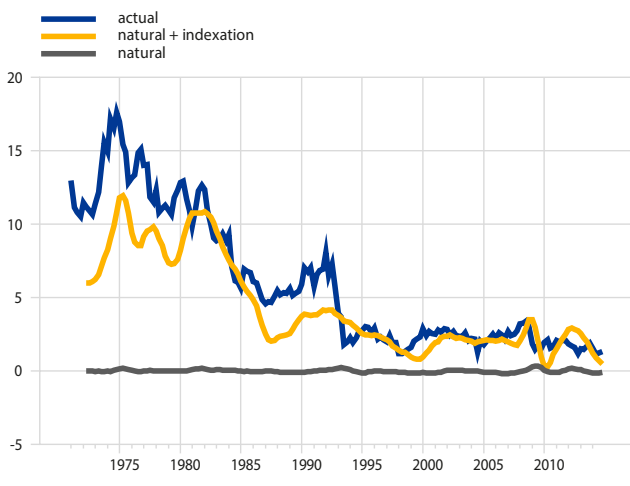
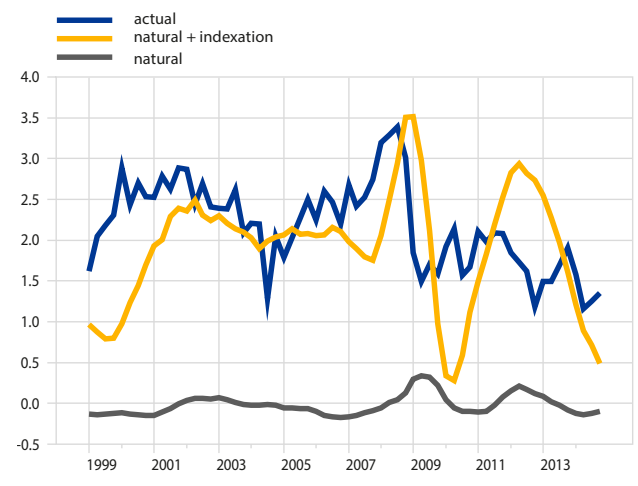


Chart 9b
Wage inflation under the natural rate hypothesis (1999-2014)



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.

⁷⁸ See Galí (2011b) for a discussion. Under the null that the model is correct, one can show $\sum_{k=0}^{\infty} \beta^k E \{ \tilde{u}_{t+k} | \mathbf{x}_t, \mathbf{x}_{t-1}, \dots \} = \sum_{k=0}^{\infty} \beta^k E_t \{ \tilde{u}_{t+k} \}$ implying that the use of current and lagged values of \mathbf{x}_t as an information set is not restrictive.

4.2 The long-run trade-off hypothesis

Under the *long-run trade-off 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 these 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: $\hat{i}_t = \phi_i \hat{i}_{t-1} + (1 - \phi_i) [\phi_\pi (\pi_t^p - \pi_t^*) + \phi_y \Delta y_t]$ 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 $\hat{i}_t \equiv i_t - (\rho + \pi_t^*)$. 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:⁷⁹ $u_t = u^n - \frac{1-\beta}{\lambda_w \varphi} \pi_t^w$

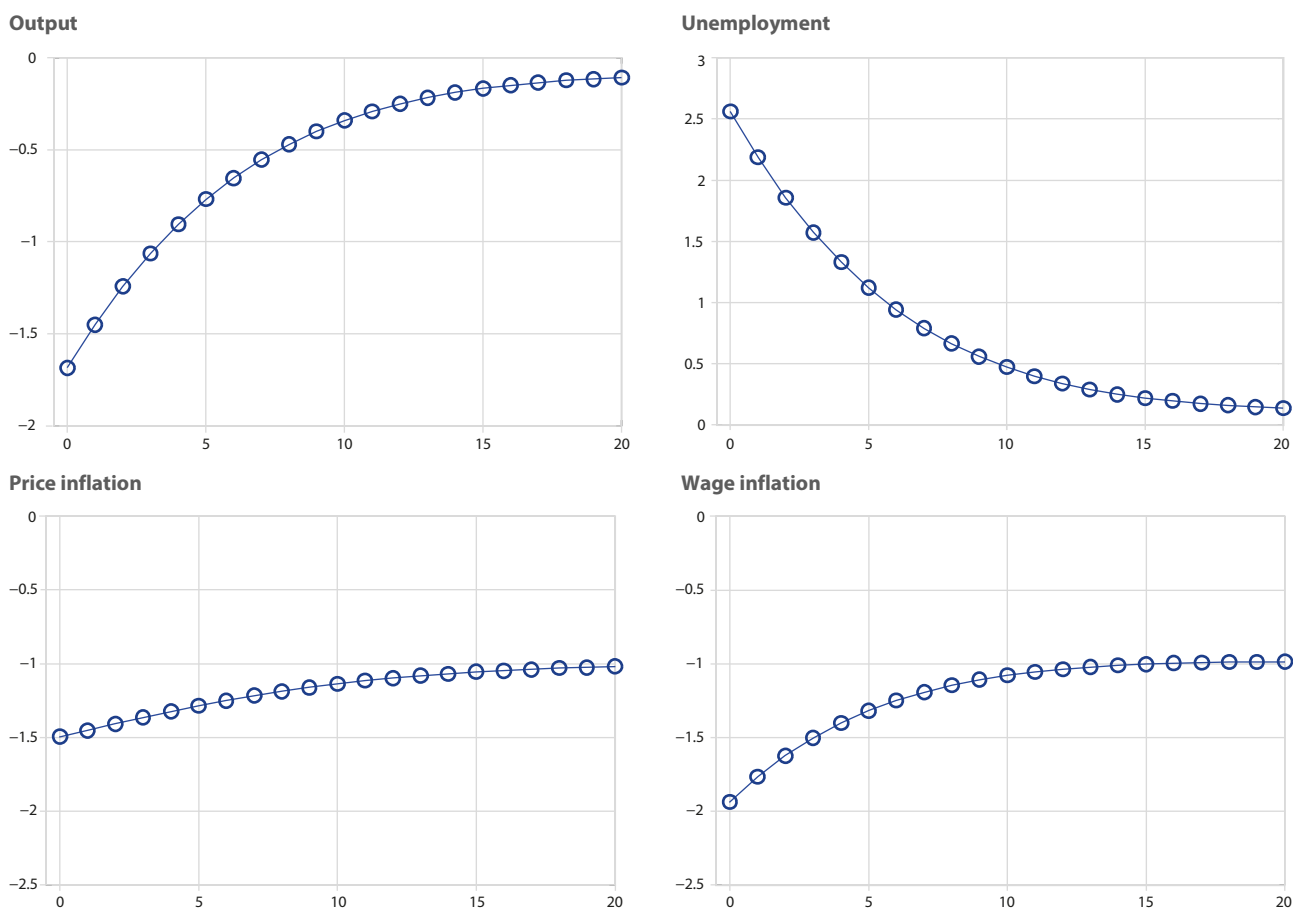
The existence of that *long run trade-off* in the NK model has a simple explanation: the “engine” of wage inflation in the model is the existence of a discrepancy between the average wage mark-up and its desired (or natural) counterpart. Accordingly, the only way to attain permanently higher wage inflation is to increase that gap or, equivalently, the gap between the unemployment rate and its natural counterpart, as implied by (8).

Chart 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 (annualised) inflation target. Note that the disinflation generates a large recession in the short run, with an output decrease of nearly 2% and a rise in 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 trade-off hypothesis, as further discussed below.

⁷⁹ In the case of partial indexation to price inflation that long relation becomes $u_t = u^n - (1 - \beta)(1 - \gamma)/\lambda_w \varphi * \pi_t^w$ where $\gamma \in [0, 1]$ is the indexation parameter. Note that the long-run trade-off vanishes in the case of full indexation ($\gamma = 1$).

Chart 10

Inflation target shock: dynamic responses

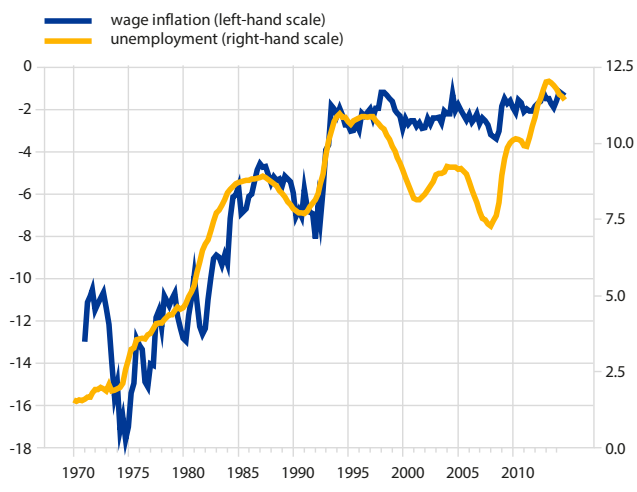


4.2.1 Empirical assessment

The long run trade-off hypothesis seems, at least qualitatively, consistent with the evidence of cointegration between wage inflation and the unemployment rate uncovered above. Chart 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.

Chart 11

A long-run trade-off between inflation and unemployment?



The estimated coefficient in a cointegrating regression of the unemployment rate on wage inflation (with the latter expressed in quarterly terms) is -2.04 ($s.e. = 0.09$).⁸⁰ If one interprets that empirical relationship as a structural one (in a way consistent with the model), that estimated coefficient implies a permanent increase of 0.5 percentage point in the unemployment rate for every percentage point of (permanent) reduction in *annualised* 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 (annualised) inflation of one percentage point

is given by $(1 - \beta)/4\lambda_w\varphi$ which, under my baseline calibration, equals 0.13, well below the 0.5 estimate.⁸¹

The long-run trade-off 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 1970s-80s) by assuming a lower value for γ . In particular, this is possible if I set $\varphi = 0.08$, implying a Frisch labour 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 trade-off 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,⁸² while the unemployment rate has persisted in its random walk-like behaviour, as Chart 11 makes clear.

To summarise: the low frequency comovement between wage inflation and the unemployment rate over the period 1975-1993 seems *qualitatively* consistent with the long-run trade-off hypothesis, which would attribute the permanent variations in the unemployment rate over that period to permanent changes in the inflation target and, in

⁸⁰ Using the shorter 1970-1993 period yields an identical estimate.

⁸¹ 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 $(1 - \beta)(1 - \gamma)/4\lambda_w\varphi$ where γ denotes the degree of indexation.

⁸² A unit root in wage inflation is easily rejected in the post-1994 period.

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 of those two variables after 1994, can be easily reconciled with that hypothesis, at least through the lens of a conventionally calibrated NK model.

4.3 The hysteresis hypothesis

In their seminal 1986 paper, Blanchard and Summers propose a theory of unemployment that emphasises 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,⁸³ is 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, giving 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 NK model, replacing the standard wage-setting condition (wx1). My assumed wage-setting rule is a limiting case of a more general rule in the NK model with insider-outsider labour markets developed in Galí (2015b).⁸⁴ 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:

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

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

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

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

$$w_t^* = -\frac{1}{\epsilon_w} n_{t-1} + (1 - \beta\theta_w) \sum_{k=0}^{\infty} (\beta\theta_w)^k E_t \left\{ w_{t+k} + \frac{1}{\epsilon_w} n_{t+k} \right\} \quad (12)$$

Thus the newly-set wage is increasing in the 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 labour 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.

⁸³ See, e.g. Gottfries and Horn (1987) and Lindbeck and Snower (1989).

⁸⁴ See Galí (2015b) for a detailed derivation and analysis of its monetary policy implications.

Rewriting (12) in recursive form and combining the resulting difference equation with (4) yields, after some straightforward algebra, a modified version of the NK wage Phillips curve:

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

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 fully-fledged NK 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”.

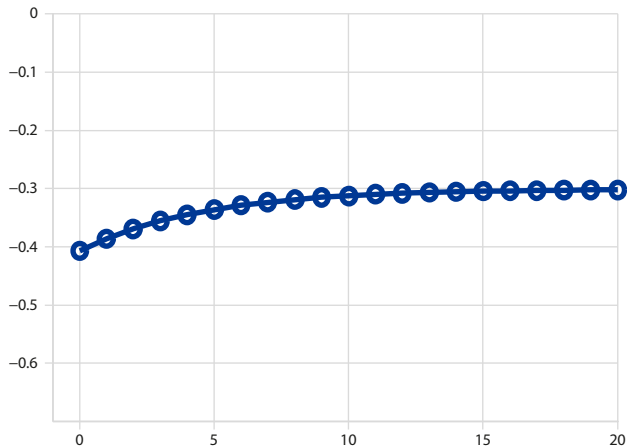
Under the assumed wage-setting arrangement, the relation between the average wage mark-up and the unemployment rate (3) is still valid. The wage mark-up (together with unemployment) evolves endogenously in response to any shock, above and beyond the fluctuations associated with wage stickiness. Note that in the present environment, and in contrast with the wage-setting model found in the standard NK model, there is no “anchor” value towards which the wage mark-up 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 “stabilise” at a level of employment and output permanently lower, and with a higher unemployment rate.

The previous phenomenon is illustrated in Chart 12, which displays the effects of a *transitory* adverse demand shock in the insider-outsider version of the NK model. The demand shock is formalised 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 emphasised by Blanchard and Summers (1986). Note also that the impact on wage and price inflation is very small.

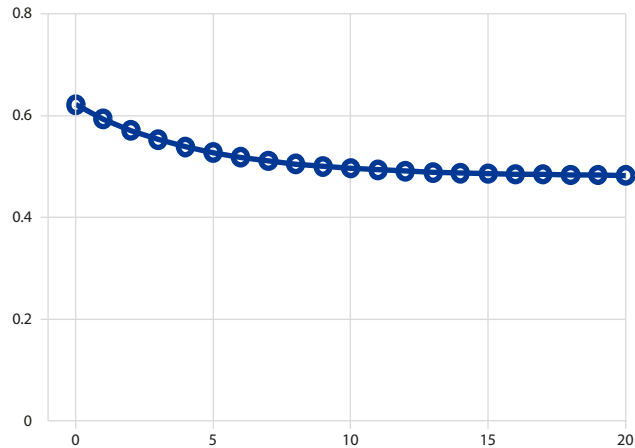
Chart 12

The insider-outsider model: dynamic responses to a demand shock

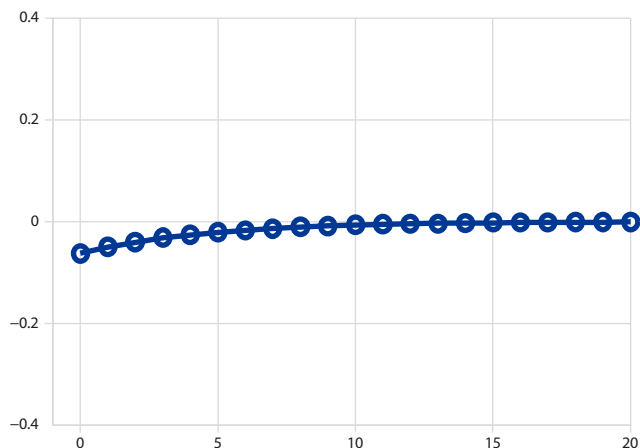
Output



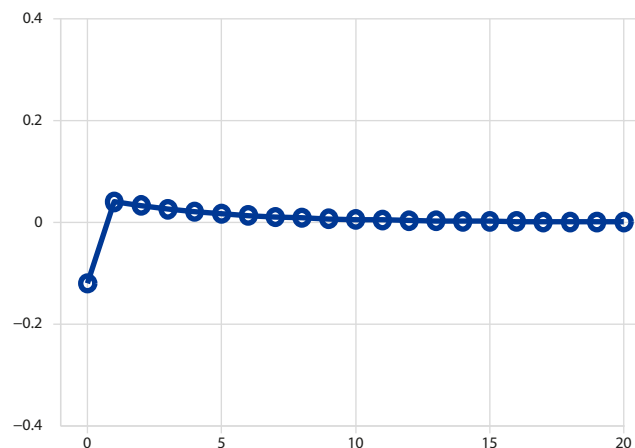
Unemployment



Price inflation



Wage inflation



4.3.1 Empirical assessment

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

$$\pi_t^w = \beta E_t \{\pi_{t+1}^w\} + \lambda_n \Delta n_t \quad (14)$$

where $\lambda_n \equiv 1 - \theta_w / \theta_w \epsilon_w$

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 behaviour 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 reoptimisation periods, as assumed earlier when evaluating the NK wage Phillips curve under the natural rate hypothesis. I assume a form of indexation which gives rise to the modified wage inflation equation:

$$\tilde{\pi}_t^w = \beta E_t\{\tilde{\pi}_{t+1}^w\} + \lambda_n \Delta n_t \tag{15}$$

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

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 $\mathbf{x}_t \equiv [\Delta n_t, \tilde{\pi}_t^w]$. Again, under the null that the model and calibration are “true”, the wage inflation series thus constructed should correspond to its empirical counterpart.⁸⁵

Chart 13a
Wage inflation in the insider-outsider NK model (1970-2014)

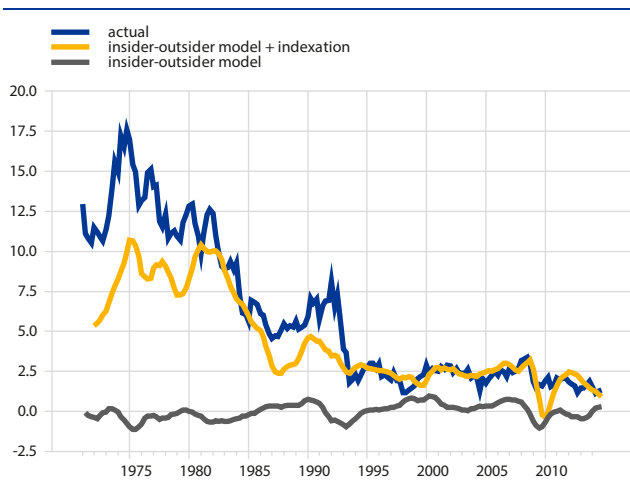
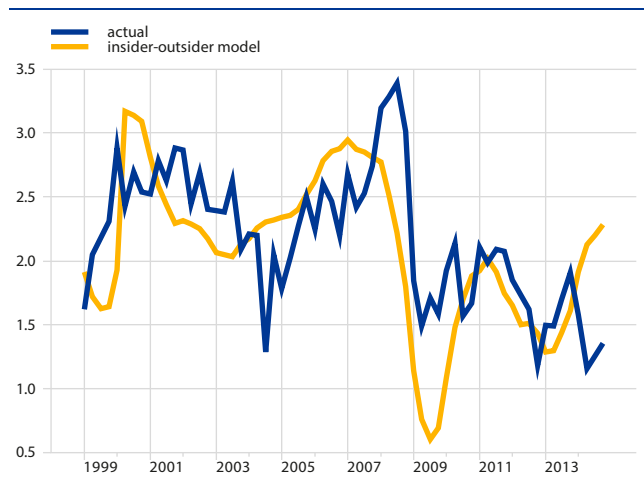


Chart 13b
Wage inflation in the insider-outsider model (1999-2014)



⁸⁵ See, e.g. Campbell and Shiller (1987). Galí (2011b) for an application to wage inflation.

Chart 13a displays the path of wage inflation predicted by the insider-outsider model with and without indexation, together with its observed counterpart. 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 behaviour of the unemployment rate.

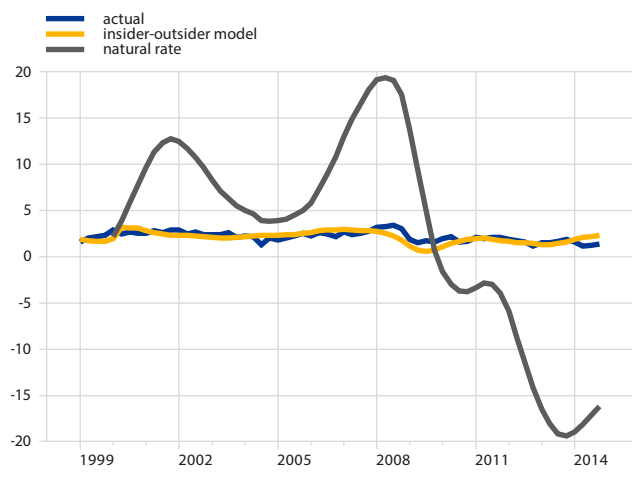
Of course, as was the case for the natural rate model analysed above, indexation together with the large low frequency variations in inflation in the early part of the sample period are responsible for much of the observed high correlation, as demonstrated by the limited variation of predicted wage inflation in the absence of indexation. Focusing on a more recent period with low and stable inflation and in which indexation is likely to have been less relevant may provide a better assessment of the model. Chart 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 Chart 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 1998-99 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.⁸⁶

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 with that generated by the constant natural rate model, and which in the absence of indexation is given by $\pi_t^w = -\varphi\lambda_n \sum_{k=0}^{\infty} \beta^k E_t \{u_{t+k} - u^n\}$

⁸⁶ 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.

Chart 13c

Wage inflation: insider-outsider vs. constant natural rate models (1999-2014)



Again, I focus on the single currency period and approximate the natural rate of unemployment by average unemployment over that period (9.4%). I use a VAR for $\mathbf{x}_t \equiv [u_t, \pi_t^w]$ to forecast future unemployment rates. Chart 13c displays the implied path for wage inflation generated by the insider-outsider and constant natural rate models, under my baseline calibration, alongside actual wage inflation. As the chart 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 NK model with insider-outsider labour 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) non-stationarity in its unemployment rate. I have sought to uncover some clues about the nature and sources of that non-stationarity by analysing the joint behaviour 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 and 2011 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 trade-off 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 behaviour of the unemployment gap implied by that hypothesis is hard to reconcile with the observed patterns of wage inflation.

The long-run trade-off 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 non-stationary 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 behaviour in euro area unemployment. Yet, a number of remarks seem warranted in light of the previous evidence.

First, 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 objective. On the other hand, it should require a stronger focus on unemployment stabilisation, 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 stabilisation can be made, as a formal analysis of optimal monetary policy under hysteresis show.⁸⁷ There are two reasons for this. First, in the absence of a counter-cyclical policy there is no "anchor" that guarantees that unemployment will revert back to some "natural" level. Accordingly, in the absence of a forceful counter-cyclical 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 trade-off, 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 labour market environment assumed in the standard New Keynesian model.

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⁸⁷ See Galí, J. (2015b).

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Appendix

Other blocks

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

$$Y_t(i) = N_t(i)^{1-\alpha} \quad (16)$$

where $Y_t(i)$ denotes the output of good i , $N_t(i)$ is a CES (constant elasticity of substitution) function of the quantities of the different types of labour services employed by firm i , whose elasticity of substitution is given by $\epsilon_{w,t}$. Cost minimisation by firms gives rise to the labour 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 mark-up 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 NK 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 mark-up 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:

$$\tilde{y}_t^n = E_t\{\tilde{y}_{t+1}\} - (i_t - E_t\{\pi_{t+1}^p\} - r_t^n) \quad (17)$$

where the output gap, $\tilde{y}_t \equiv y_t - y_t^n$ 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 mark-up gaps can be shown to hold:

$$\tilde{y}_t = -(1 - \alpha/1 + \varphi)(\tilde{\mu}_{w,t} + \tilde{\mu}_{p,t}) \text{ where } \tilde{\mu}_{w,t} \equiv \mu_{w,t} - \mu_{w,t}^n \text{ and } \tilde{\mu}_{p,t} \equiv \mu_{p,t} - \mu_p.$$

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 (annualised) return on financial assets of about 4%. I also assume $\varphi = 5$ (which implies a Frisch elasticity of labour supply of 0.2), $\alpha = 1/4$, and $\varepsilon_p = 9$ (implying $\mathcal{M}_p = 1.125$, i.e. a steady state mark-up of 12.5%). When relevant, I set $\varepsilon_w = 4.5$, a value consistent with an average unemployment rate of 5%, roughly the mean unemployment rate in the postwar US economy. I also assume $\theta_p = \theta_w = 3/4$, which imply 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
Augmented Dickey-Fuller unit root tests

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

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

Table 2
Estimated reduced form wage equations

	Q1 1970-Q4 2014		Q1 1970-Q4 1993		Q1 1994-Q4 2014	
u_t	-0.36**	-0.20**	-0.29**	-0.22**	-0.06**	-0.06**
	(0.018)	(0.023)	(0.029)	(0.034)	(0.018)	(0.019)
$\pi_{t-1}^{(4)}$		0.74**		0.53**		0.11
		(0.008)		(0.111)		(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