# MEASURING THE NAIRU IN THE SPANISH ECONOMY

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**Abstract**

This paper addresses the issue of measuring the NAIRU in the Spanish economy. We implement some of the procedures proposed in the literature to estimate the NAIRU, describing their advantages and disadvantages. Our analysis shows that these alternative approaches provide significantly different point estimates of the NAIRU. Moreover, whenever some measures of the precision of the estimate are available (Phillips-curve based estimates and SVAR estimates), the degree of uncertainty is remarkable. Thus, our main conclusion is that the usefulness of the NAIRU concept as a general guideline for discussing and analyzing macroeconomic policy is very limited, given the current state of economic research on this area. Two additional conclusions may be summarized as follows. First, all the NAIRU estimates display an upsurge between 1981 and 1985, and a drop during the last cyclical upturn that has closely tracked the decline in the observed unemployment rate. Second, the results of the structural approach point to three factors driving the changes in the NAIRU over the sample period: price mark-ups, the replacement ratio and changes in the tax system.

## 1. Introduction

Disentangling the cyclical and the structural components of the unemployment rate is an exercise whose interest is not merely academic. The deviation of unemployment from some natural rate is one among the usual ingredients framing debates on monetary policy. In these policy discussions the natural rate is commonly understood as the rate of unemployment at which inflation remains constant, and the term NAIRU (for nonaccelerating inflation rate of unemployment) is used to denote this concept. The analytical framework underlying the NAIRU concept is based on a standard Phillips-type relationship linking unexpected inflation with some measure of labor market slack. As Stiglitz (1997) has recently suggested, assessing the usefulness of this concept for policy purposes requires taking into account three factors. First, the success of the unemployment gap as a cyclical indicator helpful in predicting changes in inflation; second, the ability to obtain variables capturing the underlying factors explaining the NAIRU; and finally, an evaluation of the degree of uncertainty surrounding the estimates.

That said, and in spite of the public prominence of the NAIRU concept in the last two decades, its value as a framework for policy questions is far from being uncontroversial. The most obvious caveat regarding the usefulness of the NAIRU concept arises from the fact that alternative methodologies for measuring the NAIRU lead to important divergences in the estimates. This problem is further complicated because, although numerous methods have been developed in recent decades for estimating the NAIRU, few empirical studies provide measures of the precision of the estimates.

As the tittle states, in this paper we address the issue of measuring the NAIRU in the Spanish economy trying to document how it has changed over the last two decades. The paper provides an overview of alternative methodologies developed in the literature to measure the NAIRU and compares the different results for the Spanish economy[1]. Thus, we try to piece together alternative pieces of evidence with an additional contribution. We compare the results using data for the total economy with data for the economy excluding public sector data. The later data set is shown to be better for estimating the wage and price equations during the period 1980-1999.

In this introduction, we outline and summarize the sections into which the paper is organized. We first start, in Section 2, with univariate methods that are purely statistical procedures designed to decompose the observed unemployment time-series into a permanent component (that we identify with the NAIRU) and a transitory component

[1] Fabiani and Mestre (2000) provide a similar overview for the euro area and McAdam and Mc Morrow (1999) present NAIRU estimates arising from alternative methodologies for the US, Japan and EU-15. Previous estimates of the NAIRU for the Spanish economy can be found in: Direccion General de Prevision y Coyuntura (1991), De Lamo and Dolado (1993) and Rodriguez (1995), among others; an empirical survey of these is found in Gómez and Usabiaga (1998).

(capturing the cyclical movements in unemployment). Among the several filtering techniques that have been proposed in the literature to isolate the permanent and transitory component of a given time-series, we focus on the two most commonly used: the Hodrick-Prescott (H-P) filter and the Band-Pass (B-P) filter. Of course, these univariate methods are empty of economic structure and its use to measure the NAIRU is at odds with the NAIRU concept. The theoretical framework underlying this concept is completely absent when using these filtering techniques.

Thus, we then move to our second, more economic-based approach (Section 3) for estimating the NAIRU. It relies on the existence of a stable expectations-augmented Phillips-type relation. In this framework, the NAIRU is defined as the value of unemployment that is consistent with the existence of a Phillips relation between unexpected inflation and the deviation of unemployment from the NAIRU. The Phillips curve is estimated for alternative proxies of inflationary expectations and we also consider alternative additional assumptions that are needed to identify the NAIRU when it is allowed to vary over time. This approach is not completely atheoretical but it does not investigate which are the possible determinants of the NAIRU. The results are striking. Using this approach we find that the joint estimation of the slope of the Phillips curve and the NAIRU is subject to an empirical trade-off. Thus, on one hand we estimate a negatively sloped function at the cost of an implausible NAIRU; and on the other, to obtain more plausible NAIRU estimates the Phillips curve relationship becomes positive.

Some of the problems associated with the previous analysis stem from the importance that medium-run (i.e. persistence) movements have in shaping the patterns of both unemployment and inflation in the past two decades in Spain. To take into account such an issue, in Section 4 we provide estimates of the NAIRU on the basis of structural vector autoregression (SVAR) models. With this framework, we use the long-run identifying restrictions, which stylized models of the labor market impose on the joint dynamics of unemployment and other variables, to separate permanent and temporary shocks. Then, the NAIRU is obtained by accumulating those structural shocks with a permanent impact on unemployment. In other words, the NAIRU is defined as the unemployment rate that would prevail if only the shocks having a long run effect on unemployment were taken into account. Thus, identifying these shocks is a crucial step in this approach. We use two alternative identification schemes. In the first one, we highlight the role of inflation in identifyiung NAIRU shocks, whereas in the second one we focus on the role played by real wages in disentangling labor demand from labor supply shocks. This approach represents a first step in the direction of structural methods insofar as we are able to identify those shocks that are behind the evolution of the NAIRU. However, on the one hand, it does not provide a clear match among innovations to unemployment and observed variables; and further the uncertainty surrounding the NAIRU, although lower than in the previous analysis, is still not negligible.

In the structural approach (Section 5) the NAIRU is estimated by solving separate price and wage equations for the equilibrium unemployment rate. Under this framework, we first present the long-run price and wage equations that determine the NAIRU as the solution of the system. In addition, we present two alternative versions of the short-term dynamics of prices and wages to distinguish the standard backward-looking approach from a more recent approach that allows for a mixture of backward and forward-looking adjustment. Since the NAIRU is a function of all the variables involved in the system, this method has the advantage of identifying those labor market variables that are behind changes in unemployment.

Finally, in Section 6 we provide a comparison of the estimates of the NAIRU for the Spanish economy obtained using the different methodologies described in this paper, along with an alternative estimate of the NAIRU (calculated by the OECD). Our analysis shows that these different approaches provide significantly different point estimates of the NAIRU. Moreover, whenever some measure of the precision of the estimate are available (Phillips-curve based estimates and SVAR estimates), the degree of uncertainty is non-negligible. Thus, our main conclusion is that the usefulness of the NAIRU concept as a general guideline for discussing and analyzing macroeconomic policy is far from uncontroversial, given the current state of economic research. Two additional conclusions may be summarized as follows. First, all the NAIRU estimates display an upsurge between 1981 and 1985, and a drop during the last cyclical upturn that has closely followed the decline in the observed unemployment rate. Second, the results of the structural approach point to three factors driving the changes in the NAIRU over the sample period: price mark-ups, the replacement ratio and changes in the tax system.

## 2. Univariate methods of NAIRU estimation

In this section, we describe several purely statistical procedures that define the NAIRU using only the information on the univariate behavior of the observed rate of unemployment. These methods allow us to decompose unemployment into permanent (in general, non-stationary) and transitory (stationary, capturing the business-cycle fluctuations) components. Under this approach the permanent component is identified with the NAIRU concept. Thus, we assume that in the labor market there are underlying (but non-specified) mechanisms that drive back unemployment to its trend rate after a shock, so guaranteeing that unemployment fluctuates around the NAIRU so identified. The drawbacks of this analysis are well known. First, a priori restrictions on the underlying stochastic process for the NAIRU should be imposed to identify it. Second, these methods do not use any information about inflation developments and/or labor market variables, so nothing ensures that the estimation of such a trend component corresponds to the economic concept of NAIRU. Finally, it is not possible to evaluate the uncertainty surrounding the estimates of the NAIRU.

A considerable number of filtering techniques has been proposed in the literature to isolate the permanent and transitory components of a given time-series. In this section we have selected two, probably the most commonly used: the Hodrick-Prescott (H-P) filter (Hodrick and Prescott [1997]) and the Band-Pass (B-P) filter (Baxter and King [1999]). These two methods identify the permanent component as a weighted moving average of lags and leads of the observed time-series. Some arbitrary parameters allow the span of the moving average to be selected, thus choosing the degree of smoothing that identifies the trend component of unemployment. While the H-P filter removes the high frequency components when calculating the deviations from trend (so the noisy terms or even the seasonal terms could still be present), the B-P filter removes both the high and very low frequency components (including not only the noisiest part of the time series but also the seasonal component).

Both methods use symmetrical moving averages in calculating the trends, so this raises a specific problem in terms of the end point. Provided that at any point of time they use information of both lags and leads, when we are approaching last period, the forward information is reduced, so the estimations are less precise and they could be substantially modified with the arrival of new information. In order to minimize this drawback, we follow the recommendations of Kaiser and Maravall (1999), applying these filters to the unemployment rate enlarged with the univariate forecasts[2]. To obtain an estimation of the NAIRU we apply these filtering techniques to the observed unemployment rate[3] with the standard smoothness parameters as a benchmark. As the unemployment rate is in quarterly frequency, we set $\lambda$=1600 in the H-P filter aimed at eliminating cycles between two and eight years. For the B-P filter we eliminate the fluctuations that occur between two and thirty two quarters, and the order of the moving average is twenty-four quarters.

Given the values of these parameters, it is not surprising that, we obtained very similar NAIRU estimates using the two procedures. In both cases we observe a NAIRU that closely follows observed unemployment. Thus, the estimated NAIRU seems to be very sensitive to the business cycle.

*The predictive power of the unemployment gap on inflation*

As noted before, one of the drawbacks of these methods is that they do not use any information on inflation developments. Thus, we should test whether our trend-

[2] We use the univariate forecasts automatically supplied by the TRAMO program. Besides, for the H-P filter we do not use the observed unemployment rate, but the trend-cycle signal supplied by the program SEATS, to eliminate the noisy and seasonal components of the observed unemployment.

[3] Additionally, we have used the demographically adjusted unemployment rate. As long as, in the sample period, it is very similar to the observed unemployment, the results are not affected by this choice, so they are not reported to save space. In any case, they are available from the authors upon request.

unemployment component is a true indicator of the NAIRU. For this purpose, we have estimated traditional Phillips curves testing whether the deviation of unemployment from our NAIRU estimates determines the inflation dynamics. In this case, the regression we estimate is the following:

$$p_t - p_t^e = B(L)(u_{t-1} - u_{t-1}^*) + C(L)(p_{t-1} - p_{t-1}^e) + e_t \qquad [1]$$

where $\pi$ represents inflation, $\pi^e$ expected inflation, u unemployment, $u^*$ the NAIRU, B(L) and C(L) are lag polynomials and $\varepsilon$ is a serially uncorrelated error term[4].

In Tables 2.1 and 2.2 we have reported tests for the joint significance (p-values) of the coefficients of the unemployment gap in the Phillips curve regressions (say, the coefficients of the lag-polynomial B(L)). The robustness of the results were tested using different indicators of price inflation (CPI, underlying CPI, underlying CPI adjusted for changes in indirect taxation and GDP deflator), of wage inflation (wage survey, wages in National Accounts) and different models for inflation expectations (the lagged value -Table 2.1- or an AR(4) recursively estimated -Table 2.2-)[5].

This exercise suggests that these measures of the unemployment gap –based on univariate methods of NAIRU estimation- do not have any predictive power on price or wage inflation. The results slightly improve when an underlying measure of price inflation is used or in the case of wages, when QNA figures are taken into account. Alternatively, using univariate models to construct inflation expectations helps to increase the predictive power of the unemployment gap. Finally, the negative-positive signs of the unemployment gap implicit in the Phillips curve estimation can be well described as indicating a hysteresis mechanism[6].

Overall, this analysis has abstracted from controlling for the supply side shocks usually considered in this literature (e.g. oil shocks, taxes, etc…). We will pursue this issue in the next section, where we will jointly estimate the NAIRU and the Phillips trade-off within a unified framework.

[4] This exercise could also be understood in terms of how deviations of unemployment from NAIRU act as predictors for future inflation.

[5] In Appendix 2 we have performed a sensitivity analysis using other values for the smoothness parameters.

[6] In these Phillips-curve regressions, only the first and second lag of deviations from NAIRU are almost significant, both having a similar coefficient in absolute value, but the first with a negative sign and the second, with a positive one.

## 3. Estimates of the NAIRU based on the Phillips curve framework

The conventional wisdom for estimating the NAIRU relies on the existence of a stable expectations-augmented Phillips-type relationship (a recent example is Staiger, Stock and Watson [1997]). In this framework, the NAIRU is defined as the value of unemployment that is consistent with the existence of a relationship between unexpected inflation and the deviation of unemployment from the NAIRU (u*). A general specification for this framework would be:

$$p_t - p_t^e = B(L)(u_{t-1} - u_{t-1}^*) + C(L)(p_{t-1} - p_{t-1}^e) + D(L)z_t + e_t \qquad [2]$$

where $z_t$ is a vector of supply shock variables and $D(L)$ is a new lag polynomial. The additional regressors $z_t$ are included to control for supply shocks, which would shift the intercept of the Phillips curve. Equation [2] may be estimated for alternative inflation, inflation expectations and unemployment definitions. Moreover, some additional assumptions are needed to identify a time varying NAIRU. In our basic specification, we use data on CPI inflation and observed unemployment, and we focus on the “random walk” or acceleracionist model for inflationary expectations $(p_t^e = p_{t-1})$. Following Staiger, Stock and Watson (1997), four alternative statistical models for the time varying NAIRU are considered: Constant NAIRU, Break NAIRU, Spline NAIRU and Time-varying parameter (TVP) NAIRU. More formally, they take the following forms:

$$u_t^* = \bar{u} \qquad \text{for all t} \qquad [3a]$$

$$u_t^* = u_i \qquad \text{if } t_{i-1} < t \le t_i \text{, i=1,…I} \qquad [3b]$$

$$u_t^* = \overline{\Phi}' S_t \qquad [3c]$$

$$u_t^* = u_{t-1}^* + h_t,\ h_t \text{ IID } N(0, s_h^2),\ Eh_t e_t = 0 \text{ all t,}\tau \qquad [3d]$$

The first of these models (equation [3a]) assumes that the NAIRU does not change over time. The remaining three models make use of alternative statistical assumptions to allow the NAIRU potentially to vary over time[7]. In the break model (equation [3b]), the NAIRU is constant between break dates ($t_i$). Given our sample period (1980-1999), we

[7] As an alternative to these statistical assumptions, economic assumptions may be used to identify a time-varying NAIRU. For this purpose, equation [2] may be estimated modeling the NAIRU as a function of observable labor market variables (see Staiger, Stock and Watson. [1997]). This approach is pursued in the broader context of estimating price and wage equations in section 5 of this paper. In fact, expression [2] may be considered as a reduced form of a structural wage-price setting model.

consider only one break date (1985:1). In the spline model (equation [3c]), the NAIRU is approximated by means of a vector of deterministic function of time ($S_t$). In our case, we consider a cubic spline with two knots (1985:1 and 1990:1). Finally, in the TVP model (equation [3d]), the NAIRU follows a random walk process and is allowed to vary by a limited amount each quarter. The limit on the size of the variation is given by the standard deviation $\sigma_\eta$[8].

Table 3.1 presents estimates of equation [2] for the alternative statistical models of the NAIRU (equations [3a] to [3c]) using data on CPI inflation and total unemployment for the period 1980:1-1999:3 and assuming that expected inflation can be proxied by lag inflation (accelerationist Phillips curve). To control for the existence of supply shocks, we also include three variables in the specification of the Phillips curve. First, the difference between unprocessed food inflation and overall CPI inflation (PF_CPI); second, the difference between energy inflation and overall CPI inflation (PE_CPI); and finally the difference between non-energy import prices inflation and overall CPI inflation (IVU_CPI)[9]. The row labeled B(1) in Table 3.1 corresponds to the estimated sum of coefficients for the lags of unemployment entering in equation [2]. The following rows show the unemployment rate and the corresponding estimated NAIRU for those quarters in which the observed unemployment rate reached a local maximum or minimum and for the last quarter of our sample.

Although the idea of NAIRU being constant is not a very realistic one, it provides a benchmark to compare alternative estimates. In this respect, two comments are worth mentioning. First, the time pattern of the signs of the unemployment gap obtained from the constant NAIRU estimate does not differ substantially from that obtained with the univariate filtering techniques. Second, the fit of the constant NAIRU model is not significantly lower than the fit of models allowing the NAIRU to vary over time. This simply reflects the importance of the uncertainty surrounding these estimates.

When estimating a break NAIRU model, the choice of the breaking points is not a trivial task. In our case, given the short sample period available, we decided to consider just one break (first quarter of 1985). The results in terms of the goodness of fit, the precision of the estimates and the signs of the implicit unemployment gaps do not differ markedly with respect to the constant NAIRU estimates. In the light of Table 3.1 we observe that the slope of the Phillips curve, B(1), is negative and significant, except for the spline model. In that

[8] See Gordon (1997), for details on the TVP NAIRU model.

[9] Four lags of each right-hand variable have been included. Nevertheless, non-significant lags have been removed from the final specifications.

case, B(1) is non-significantly different from zero. This result is a case of special interest because the NAIRU is not identified from the Phillips relation[10].

Time series of the estimated NAIRU and their associated 95% confidence interval are plotted in Figure 3.1 for this specification. As suggested by this figure, the uncertainty associated with the spline model is enormous: the range of the 95% confidence band for the NAIRU estimate oscillates from 5 to 18 percentage points throughout the sample period. This is precisely the point emphasized by Staiger, Stock and Watson (1997).

In the case of the TVP NAIRU, the assumption about the size of the standard deviation $\sigma_\eta$ determines the volatility of the NAIRU estimates. It turns out to be a crucial assumption. Figure 3.2 displays the NAIRU estimates for alternative values of $\sigma_\eta$. If we choose a small value for the standard deviation (0.01), we observe a very smooth NAIRU estimate[11]. However, highly variable NAIRU estimates are obtained for large values of $\sigma_\eta$. The standard approach is to choose a low value for $\sigma_\eta$ given that the changes in the NAIRU are driven by the microeconomic structure of the labor market, which in principle suggests that it would change slowly. In Table 3.2 we report the results of the TVP model for alternative values of $\sigma_\eta$. If we focus on the case where $\sigma_\eta$=0.02, the NAIRU is well identified and it exhibited an upward trend from the beginning of the sample until 1986:2. Then it slightly declined until 1991 when the downward trend became more pronounced. After reaching a minimum in 1993:2, increased sharply until 1995:2 and then edged down gradually. The results of the TVP model are quite unsatisfactory. For instance, the NAIRU estimate displays a substantial drop during 1992 and part of 1993, which is difficult to justify on the grounds of any development in the labor market.

Furthermore, we have investigated the sensitivity of the results presented in Tables 3.1 and 3.2 to a variety of specification changes. The results of this robustness analysis are presented in Appendix 3. First, we have considered inflation series computed using alternative prices/wages indicators: CPI excluding food and energy, CPI excluding food, energy and taxes, GDP deflator, National Accounts wages. Second, as an alternative measure of inflation expectations we have considered a recursive AR(4) forecast. This sensitivity analysis reinforces the conclusion that the value of unemployment corresponding to a stable rate of inflation is imprecisely measured.

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[10] When B(1)=0, the level of unemployment does not enter the Phillips equation. It only enters in first differences. Note that equation [1] may be written as: $p_t - p_t^e = m + B(1)u_{t-1} + B^*(L)\Delta u_{t-1} + C(L)(p_{t-1} - p_{t-1}^e) + D(L)z_t + e_t$ where $m = -B(1)u^*$ and $B_i^* = -\sum_{j=i+1}^{p} B_j$

[11] Note that when $\sigma_\eta$=0 the TVP model collapses to the constant NAIRU model.

A conclusion may be drawn from the previous analysis. The estimates of the NAIRU based on the traditional Phillips curve framework are quite imprecise insofar as, for all the estimated models, there is a wide range of values of the NAIRU that are consistent with the empirical evidence. This conclusion should be stressed if we take into account that the confidence intervals presented in this section only incorporate uncertainty about the parameters –given a particular model- but do not include the uncertainty arising from the choice of specification. Besides, we are not still able to explain why the NAIRU changes, something that we will try to focus on in the next two sections.

## 4. Measuring the NAIRU: a SVAR Approach

Recently, some authors have attempted to explain the rise and dynamics of unemployment by using the restrictions that stylized models of the labor market impose on the joint dynamics of unemployment and other variables. This view is based on two assumptions: first, that Spanish unemployment must be explained as the outcome of a combination of shocks, and second, that hysteresis mechanisms are partly responsible for the observed persistence in unemployment fluctuations. These assumptions are adequately handled within Structural Vector Autoregressive (say, SVAR) models[12]. Still, this literature has hardly focused on the implications of the SVAR methodology as a suitable device to compute long-term movements in the unemployment rate as a proxy for the concept of NAIRU[13]. This is the main objective of this section. As a by-product of the analysis we will be able to relate the unemployment gap to the output, inflation and real wage gaps. We use two alternative identification schemes. In the first, we highlight the role of inflation in identifying NAIRU shocks, whereas in the second we focus on the role played by real wages in disentangling labor demand from labor supply shocks.

### 4.1. Identifying NAIRU shocks from inflation and output dynamics

For the Spanish case, we consider that a stationary representation of inflation, output (y) and unemployment is one in which these variables appear in first differences[14]. This means that the rate of growth of output is stationary, and hence it cannot change permanently in response to inflation shocks. Thus, the long run real effect of inflation, if any, would affect the level of output but not its permanent rate of growth. The representation for the unemployment rate deserves a more thorough discussion. Most studies of the Spanish labor market highlight the role of persistence meaning that the history of shocks is crucial in

[12] See Dolado and López-Salido (1996, 2000), Andrés, Doménech and Taguas (1996), Dolado and Jimeno (1997), and Viñals and Jimeno (1997).

[13] As far as we know, Astley and Yates (1999) are the only exception.

[14] See Appendix 1, where we present the available sample period and definition of the variables as well as unit root tests for these variables.

explaining the current level of unemployment[15]. The non-stationary representation of unemployment has sometimes been considered as a sign of full hysteresis making current unemployment dependent on any shock in the past, thus, giving rise to a permanent trade-off between inflation and unemployment. But such a permanent trade-off is hard to find in the data and requires quite extreme assumptions about the functioning of the labor market. Hence, although we adhere to the unit root representation for stationary unemployment we shall impose that no such trade-off exists and that the unit root of unemployment is not driven by price surprises. In order to check the robustness of our results, in subsection 4.2 we shall also present results allowing for nominal shocks affecting long-term unemployment.

Let us consider a 3-variable VAR model, in which the vector X is defined as {$\Delta\pi$, $\Delta$y, $\Delta$u}. The system is driven by three orthogonal shocks that will be labeled in a way that enables us to use some well known theoretical relationships in the identification process: nominal ($\varepsilon^{\pi}$), supply ($\varepsilon^{y}$) and natural rate of unemployment ($\varepsilon^{u}$) shocks. These shocks are loosely defined and they might be compounded of a larger set of innovations. However, what is crucial for our purposes is the ability of the model to isolate the NAIRU shock, whose long-run real effect is what we are interested in. The structural model in matrix form can be represented as:

$$\begin{bmatrix} \Delta p \\ \Delta y \\ \Delta u \end{bmatrix} = \begin{bmatrix} c_{11}(1) & c_{12}(1) & c_{13}(1) \\ c_{21}(1) & c_{22}(1) & c_{23}(1) \\ c_{31}(1) & c_{32}(1) & c_{33}(1) \end{bmatrix} \begin{bmatrix} e^{p} \\ e^{y} \\ e^{u} \end{bmatrix} \qquad [4]$$

In order to identify the model, we can invoke three well-known economic restrictions usually considered in the literature. First, the extreme monetarist assumption, i.e. that inflation is a monetary phenomenon in the long run. This assumption means that the unit root of inflation is just money growth and it provides two restrictions in the matrix of long run multipliers; i.e. $c_{12}(1)=c_{13}(1)=0$. Second, the assumption that monetary shocks do not generate a long-run trade-off between inflation and unemployment [$c_{31}(1)=0$]. Finally, according to most theories of the natural rate (Layard, Nickell and Jackman [1991]), productivity (output) shocks cannot explain the unit root of unemployment, i.e. $c_{32}(1)=0$.

Notice that this set of assumptions provides four identifying restrictions and, consequently, the model is overidentified[16]. Using Spanish quarterly data for the period

[15] See, for instance, Andrés (1993), Bentolila and Dolado (1994), Blanchard *et al.* (1995), Blanchard and Jimeno (1995), Dolado and López-Salido (1996, 2000), and the references therein.

[16] This is so because we also impose the assumption of orthogonality of the $\varepsilon$'s in the SVAR. See Appendix 3 in Andrés, Hernando and López-Salido (1998) for details.

1980:1-1999:3, these theoretically appealing restrictions are jointly rejected[17]. The reason is that the observed long-run non-zero correlation between inflation and unemployment cannot be explained by models generated by those restrictions, since the sources of inflation and unemployment fluctuations in the long-run are imposed to be orthogonal. In other words, while inflation is explained only by nominal shocks, these shocks do not contribute to explaining the observed upward trend in Spanish unemployment. In fact, all models imposing $c_{12}(1)=c_{13}(1)=c_{31}(1)=0$ are rejected by data, regardless of whether the model is enlarged with additional long-run (i.e. $c_{32}(1)=0$) or short run restrictions[18].

In order to reconcile the model with the facts, we can consider two alternative sets of identification schemes. First, if our identification strategy relies on the monetarist assumption but allows for a long-run negatively sloped Phillips curve (i.e. removing $c_{31}(1)=0$), then nominal $\varepsilon^{\pi}$ shocks are alone responsible for the common trend between inflation and unemployment. Alternatively, we can assume a long-run vertical Phillips curve but considering the possibility of more than one shock driving the process of inflation in the long-run (i.e. removing $c_{12}(1)=0$, $c_{13}(1)=0$, or both). In such a case, low frequency relationship between inflation and unemployment is due to real shocks. In this paper, we pursue this latter alternative[19].

### 4.2. Long-term unemployment, full hysteresis and real wages shocks

In the previous section we have stressed the role of long-run movements in inflation in identifying NAIRU shocks. Within the same SVAR methodology, some authors (see Dolado and López-Salido (1996) and Dolado and Jimeno (1997)) have stressed the role of real wages in disentangling the sources of fluctuations affecting long-term unemployment. Thus, Dolado and López-Salido use information on the difference between the growth of nominal wages and inflation to impose long-run restrictions on the dynamics of real wages. In particular, they advocate a simple insider-outsider model to describe the joint dynamics of real wages, output and unemployment as follows:

$$\begin{bmatrix} \Delta(w-p) \\ \Delta y \\ \Delta u \end{bmatrix} = \begin{bmatrix} c_{11}(1) & 0 & 0 \\ c_{21}(1) & c_{22}(1) & 0 \\ c_{31}(1) & c_{32}(1) & c_{33}(1) \end{bmatrix} \begin{bmatrix} e^{w-p} \\ e^{y} \\ e^{u} \end{bmatrix} \qquad [5]$$

[17] The test of the overidentifying restriction (distributed $\chi^2$ with one degree of freedom) was 6.98 (p-value = 0.008). See Roberts (1993) for a description of this test.

[18] This result is in line with those presented by Dolado and López-Salido (2000), Dolado, González-Páramo and Viñals (1999) and Andrés, Hernando and López-Salido (1998).

[19] Andrés, Hernando and López-Salido (1998) compares the two alternatives.

where (w-p) represents real wages. This real variable allows us to focus on medium run real wages shocks (say technology shocks) as opposed to nominal shocks. Thus, the shocks in expression [5] can be labeled as follows: labor demand or technology ($\varepsilon^{w-p}$), aggregate demand ($\varepsilon^{y}$), and labor supply ($\varepsilon^{u}$). Notice that there are no "NAIRU" shocks, but instead long-term unemployment is affected by all shocks given the hypothesis of full-hysteresis. That is to say, as is well known in the labor market literature, in a full-hysteresis framework there is no a well-defined NAIRU, but instead a (long-run) trend for the unemployment rate. In the next section, we will compare the estimates following this approach with those obtained using the output and inflation dynamics.

### 4.3. Measuring movements in the NAIRU

Having shown how we have identified structural shocks we proceed now to discuss the decomposition of unemployment into its trend and cycle components. We will call NAIRU the trend or long-run component of the associated multivariate Beveridge and Nelson (BN) decomposition of the SVARs. This analysis is based upon the dynamic effects of the different structural shocks at zero frequency (see Evans and Reichlin (1994) for details)[20]. Thus, in the first SVAR the NAIRU is defined in terms of the unemployment long-run forecast with respect to the information set formed by its past history according to the identification scheme. In the second SVAR we use information on real wages allowing for full hysteresis so we call to the long-run forecast trend unemployment or long-run unemployment instead of NAIRU. More formally, the multivariate BN decomposition implies that long-run unemployment or the NAIRU is defined in terms of the following forecast: $E_t\Delta u_{t+k}$. In particular, we start by the long-run restrictions by defining long-run unemployment as follows:

$$\Delta u^T = C(1)e_t \qquad [6]$$

Notice that, as stressed by Evans and Reichlin (1994) this implies that only some structural shocks determine the long-term movements of the variable, but all the reduced form residuals from the VAR will affect the trend-pattern of the variable.

### 4.4. Results

The main aim of this section is to exploit the previous identification schemes to compute a long-term unemployment rate compatible with the usual NAIRU concept. Nevertheless, the methodological framework adopted also allows us to decompose output,

[20] An alternative definition (Blanchard-Quah (1989)) will be as follows: $\Delta u^T = C(L)e_t$ which now defines the permanent component as stemming from the dynamic effect, at time horizon, of the shocks on unemployment. That is, once we have identified the shock as permanent, both its short and long term dynamics effects define the trend component.

inflation and real wages into their trend and cycle components. Figure 4.1 presents the trend-cycle decomposition of unemployment, inflation and output resulting from the identification scheme described in section 4.1, i.e. when inflation has a real source of long-run fluctuation and when nominal shocks are not part of the unit root of unemployment.

The upper left panel of Figure 4.1 depicts the estimated NAIRU (with its confidence interval) along with current unemployment. The NAIRU series displays a smooth pattern that seems to be properly capturing the structural component of the rate of unemployment. Nevertheless, these estimates suggest that the NAIRU might be excessively sensitive to cyclical conditions (i.e. the NAIRU follows the actual rate to some extent), at least for the final part of the sample period.

From the analysis of the cyclical downturns in the sample period, we observe that most of the increase in unemployment has a cyclical rather than a structural origin. This is specially the case in the recession of the early nineties when the observed rate of unemployment rocketed from 15.8 % in the second quarter of 1991 to 24.4 % in the first quarter of 1994. In this same period the NAIRU rose from 21.2 % to 23.3 %. Although these figures suggest that most of the upsurge in unemployment had a transitory nature, there is a structural component in the increase of unemployment that remains to be explained.

The behavior of the NAIRU in the expansions contained in the sample period is interestingly different. During the cyclical upturn of the late eighties, the NAIRU displayed an upward trend, while the unemployment rate fell by 6 percentage points. However, in the last expansion the drop in the NAIRU (from 19.3 to 15.9 between the third quarter of 1996 and the third quarter of 1999) has closely followed the decline in the observed unemployment rate (from 21.9 to 15.5 in that period). This means that the current expansion in employment is not exerting too much pressure on prices so far, and that this is likely to continue as long as the unemployment gap remains near to zero.

The estimation of the SVAR models allows us to compute a measure of the output gap, taking into account the contributions of the disturbances that have a transitory effect on output. The lower right panel of Figure 4.1 displays the output gaps obtained with the identification scheme introduced in section 4.1. As the output gap is not an observable variable and there are numerous methods to decompose a series into its trend and cycle component, it is useful to compare our output gap estimates with another measure widely used in the Spanish economy. This measure is computed following the procedure described in Álvarez and Sebastián (1998), using a structural dynamic model with long-run identifying restrictions in the spirit of Quah and Vahey (1995). In Figure 4.1 shaded areas indicate cyclical upturns identified as in Álvarez and Sebastián (1998). Our output gap estimate displays a similar profile to that obtained by Álvarez and Sebastián. This is especially the case for the first half of the sample period. However, the last cyclical trough is identified at the end of 1996 with our measure while with the Álvarez and Sebastián procedure it is identified at 1994.

Finally, figure 4.1 also displays the trend and cycle components of inflation. The trend component is obtained by integrating the disturbances that have a permanent effect on inflation whereas the cycle component is derived taking into account the contributions of the disturbances that have a transitory effect on inflation. In Table 4.1 we have reported tests for the joint significance (p-values) of the coefficients of the unemployment gap (i.e. the difference between observed unemployment and the NAIRU according to the SVAR) in Phillips curve regressions. The robustness of the results were tested using changes in different measures of price inflation (CPI, underlying CPI, underlying CPI adjusted for changes in indirect taxation and GDP deflator), or wage inflation (wage survey, wages in National Accounts) and the first column reflects the cyclical inflation component according to the SVAR estimates. This exercise suggests that these measures of the unemployment gap –based on SVAR- have predictive power on the cyclical component of inflation and only on two definitions of changes in inflation, based on underlying CPI and wages. The predictive power on CPI inflation is almost nil.

Figure 4.2 compares the trend-cycle decomposition of unemployment resulting from the identification scheme using the output and inflation dynamics (described in section 4.1) with the trend-cycle decomposition arising from an identification scheme that allows for nominal driven full hysteresis (described in section 4.2). As expected, the NAIRU obtained in the second case follows more closely observed unemployment to the extent that shocks have long-lasting effects. Consistently, unemployment gaps are smaller. Finally, the sign of the unemployment gap differs at the beginning and at the end of the sample period.

So far, nothing has been said, beyond hysteresis phenomena, on labor market variables that supposedly determine the changes in the NAIRU. Although these variables could have been introduced in the last two sections, we prefer to do this in the more traditional environment of wage-price setting, which we develop in the next section.

## 5. The structural approach to the NAIRU estimation

The minimum requirements to determine the NAIRU in a structural approach involves the specification of two equations: the price equation (price-setting or labor demand curve) and the wage equation (wage-setting or labor supply curve). As is going to be shown, each equation determines one a priori labor share, so we can define the NAIRU as the unemployment rate that equalizes both labor shares. Obviously, given the changes in the NAIRU and productivity, these two equations allow us to retrieve the real wage and the unemployment rate.

In this section, we first present the theoretical derivation of the price and wage equations in the long-run that allow us to determine the time-series changes in the NAIRU as the solution of the system. After estimating both equations, we consider alternative representations of the short-term dynamics, considering a pure backward-looking model and a mixture of backward and forward-looking adjustment.

## 5.1. The price and wage settings

The selected approach is based on the models developed in Layard, Nickell and Jackman (1991), where firms and trade unions interact to determine employment and real wages. Besides, we assume that firms decide the employment level after knowing the wages that will result from a negotiation between firms and trade unions. Here we focus on the equations characterizing prices and wages developments leaving for Appendix 4 the formal derivations of the expressions.

### 5.1.1. The price equation

The representative firm is characterized by a certain monopoly power in the product market and its target is to maximize profits. Taken as given are wages, demand, competitor prices (including import prices) and capital stock to decide the prices being charged, the employment hired and production. We assume that production is characterized by a Cobb-Douglas production function with constant returns to scale on employment and capital. The price equation takes the following (log-linear) form:

$$p = \Psi_p + \ln(1+m) - b\ tr + \frac{1-a}{a}(y-k) + w \qquad [7]$$

where $p$, $tr$, m, $y$, $k$ and $w$ represent the (log of) price, a time trend that captures exogenous technological progress, the mark-up, output, capital stock and nominal wages. Finally, $\Psi_p$ is a constant, ß represents the exogenous rate of growth of technological progress and $\alpha$ is the elasticity of output to employment in the production function. Given the degree of openness of the Spanish economy, we consider that domestic mark-up is going to be positively related to the relative price of imports to domestic prices[21]. This means that an increase in international prices makes the domestic demand less elastic. Thus, when external prices are high, domestic firms can raise their prices and expand their mark-ups.

[21] In the empirical application we relate the markup to the relative price imported to domestic goods. This can be understood in terms of a generalized translog demand where the price elasticity, and so the markup is not constant (see, for a recent discussion, Bergin and Feenstra [2000]).

### 5.1.2. The wage equation

Following the wage bargaining model described by Layard, Nickell and Jackman (1991) the wage setting, in a log-linear way, is given by the following equation:

$$w_0 = \Psi_w - \frac{1-a}{a}(y-k) + b\ tr - c_1 u + c_2 j\ + c_3 b + c_4\ g + p_0 \qquad [8]$$

where $\Psi_w$ is a constant, and $c_1$, $c_2$, $c_3$ and $c_4$ are positive parameters. Finally, $w_0$ and $p_0$ are the wages and prices relevant for workers, u is the unemployment rate, $\varphi$ is a set of other variables that increases the probability of finding a job at given levels of unemployment, $\gamma$ measures union bargaining power and b is the replacement ratio, i.e. unemployment benefits as a proportion of nominal wages.

In the presence of taxes and imported goods the relevant prices and wages are not the same in the price equation (expression [7]) and in the wage equation (expression [8]). In the case of firms (price setting), wages (w) should include the direct taxes on labor (social contributions and income tax on labor, $t_1$), and prices (p) should refer only to the goods and services produced domestically and excluding indirect taxation ($t_2$). In the case of the workers, wages ($w_0$) should exclude all the direct taxes on labor and prices ($p_0$) should include not only indirect taxes but also the prices of imported goods. Thus, the following relationship could be established between these concepts:

$$w_0 - p_0 = w - t_1 - t_2 - p - (p_0 - t_2 - p) \qquad [9]$$

expression [8] could be reformulated as follows:

$$w = \Psi_w + t_1 + t_2 + (p_0 - t_2 - p) - \frac{1-a}{a}(y-k) + b\,tr - c_1 u + c_2 j\ + c_3 b + c_4\ g + p \qquad [10]$$

This equation represents our basic specification for wage setting. Nevertheless, in the empirical model we allow taxes and the relative price to be entered with a coefficient other than one, to control for the capacity of workers to protect their wages from changes in taxation or external shocks. Using [10] and [7] the NAIRU ($u^*$) would be computed as (up to a constant):

$$u^* = \frac{1}{c_1}\ln(1+m) + \frac{c_2}{c_1} j\ + \frac{c_3}{c_1} b + \frac{c_4}{c_1}\ g + \frac{c_5}{c_1} t_1 + \frac{c_6}{c_1} t_2 + \frac{c_7}{c_1}(p_0 - t_2 - p) \qquad [11]$$

As can be seen, the NAIRU would be the result of changes in factors affecting labor demand (the mark-up), and factors affecting labor supply such as the replacement ratio, taxation, external shocks, power of the trade unions, etc. Apparently, if we calculate the NAIRU period by period in this way there is no room for a hysteresis phenomenon, but it is necessary to bear in mind that we will use the observed path of variables that could potentially be affected by the cycle.

### 5.2. Long-run estimation results

The equations described in the last sub-section establish the long-run course of prices and wages. The estimation of these two expressions allows us to recover the time-series changes in the NAIRU (u*). Besides, the residuals of these equations constitute the deviations of prices and wages from their long-run values, so proxying price and wage mark-ups. They will be used in the next two sub-sections to estimate the short-run dynamics of these two variables.

The econometric strategy adopted here is first to estimate each equation separately using a quarterly data-base covering the period 1980:Q1 to 1999:Q3[22], deciding the relevant variables taking into account the significance level and the contribution to the stationarity of the residuals. Once the individual equations are satisfactory, they are jointly estimated. In the estimation, we have imposed two constraints. On one hand, static nominal homogeneity –i.e. the variables on the left-hand side are not the nominal prices and wages but their real counterparts-. On the other, $\alpha$, the technical weight of labor in the production function was calibrated using the labor share.

Table 5.1 reports the main results for the two equations using two different definitions of the economy. The first two columns refer to the estimates using the data for the whole economy while the last two report the results for the private sector. There are, *a priori*, some reasons favoring the results using the private sector. First, prices in the public sector are an accounting artefact; and second, public employment and wages are conditioned by public finance considerations.

The parameter $\beta$ was lower for the whole economy, implying an autonomous yearly growth of value added of 0.4%; for the private sector it would be 0.5%. The effect of relative import prices on mark-ups is estimated to be 0.11, well below the weight of nominal imports on value added (20%). In the wage equation, unemployment has a negative impact, as expected, and higher, in absolute terms, when the private sector is considered. In any case the coefficient is quite low when it is compared with other studies[23]. The replacement ratio has a positive coefficient and finally, taxes have a very significant effect. For the whole economy workers are capable of transmitting 50% of direct tax changes to labor costs and

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[22] The details of the construction and definition of the variables considered are provided in Appendix 1.

[23] For instance, in De Lamo and Dolado (1991), the point estimate for this coefficient is –1.31.

33% of the indirect taxes. For the private sector, only changes in direct taxes are transmitted but to a larger extent (70%).

Although these two equations were the preferred ones, we tried alternative specifications in the wage equation aiming to capture some of the effects suggested by the theoretical model. For example, as proxies for the factors that change the probability of finding a new job given the unemployment rate, we tried the vacancy ratio, a variable of mismatch, the percentage of long-term unemployment and changes in unemployment. In order to capture changes in the bargaining power of trade unions we have used the percentage of people involved in strikes and the ratio of people with temporary contracts. The ratio of import prices to the GDP deflator (the other component of the wedge) was also included. None of these variables were significant. For the price equation we also tried the unemployment rate and its variation, to capture the cyclical behavior of the mark-ups, and it was not significant. This implies that real rigidity of prices is higher than that of wages.

At first sight, the estimations for the whole economy and for the private sector seem to be quite similar in terms of the estimated parameters, but the behavior of their respective residuals prevent us from using the whole economy results. As can be seen in the last rows of the table, while the residuals for the whole economy fail to pass the ADF cointegration tests at the standard levels of significance, this is not the case for the private sector. Besides, these results were confirmed when we tried to specify the short-run and the t-ECM cointegration tests were calculated. For these reasons, in what follows we will focus on the results for the private sector.

Before describing the short run dynamics, we use the estimated wage and price equations for the private sector to construct our NAIRU. This time-series and the observed unemployment are displayed in Figure 5.1. From this chart it can be seen that $u^*$ showed a steady increase until 1984, then, stabilizing thereafter at a quite high level (close to 20%) till 1990. After 1994 it began to decrease, starting now at slightly over 13%. In order to assess the main factors behind the changes in the NAIRU, in Figure 5.2 we have calculated the contributions of the different explanatory factors to the yearly variation in the estimated $u^*$. From this figure it is clear that in the sample period the evolution in the direct taxation and in the relative price of imports have played a major role in the changes in the NAIRU, the replacement ratio being somewhat marginal[24]. In the first three years, both the increases in direct taxation and in the relative price of imports contributed to increasing the NAIRU, with the replacement ratio acting as a counterweight. The implicit tax rate in 1984 was four percentage points above the 1980 rate, mainly due to Social Security contributions. The relative price of imports was boosted in this period not only by the peseta devaluation but

[24] These results are consistent with Daveri and Tabellini (1997), who highlight the important role of the tax system in explaining cross-country differences in the unemployment rate.

also by the increases in oil prices. The negative contribution of the replacement ratio was the result of a reduction of the coverage ratio, as youth cohorts and women joined to the labor market.

In the NAIRU stability period, the increase in the tax rate (mainly due to income tax) was counteracted by the decrease in the relative price of imports, when the peseta showed less weakness and oil prices fell to pre-shock levels. The contribution of the replacement ratio proved to be insignificant, in spite of the 1984 increase in the generosity of benefits and the greater turnover associated with the introduction of temporary contracts. Perhaps the differences in the wage levels of temporary and permanent workers help explain the absence of increases in the replacement ratio. Until 1993 taxes and the relative price of imports continued counterbalancing each other, so the increase in the NAIRU was the result of the increase in the replacement ratio, since the coverage was widening as a result of the extension of unemployment assistance benefits. In 1992, due to the poor performance of the Social Security deficit, there was a cut in the generosity of benefits, which become apparent in data only after 1994 when the NAIRU began to diminish. Moreover, in 1995 these incomes were included in the tax base of income tax, deepening the negative impact on NAIRU. The other two determinants also contributed to reducing the NAIRU in this period. In the first place, in 1995 a reduction in Social Security contributions was financed with increases in indirect taxation, and from 1997 there were further reductions, associated with the creation of jobs in specific groups. Especially by the end of the period, there were also cuts in income tax. More surprising is the absence of effects of the devaluation of the peseta in 1993 and 1994, but we did not observe any such impact in relative prices.

In Table 5.2 we have performed some tests to assess the relevance of the NAIRU gap for forecasting the changes in wage or price inflation. As can be seen, their ability to anticipate price inflation is quite low, as occurred with the other measures of the NAIRU, and it works well when wage inflation is considered.

### 5.3. Price and wage short run dynamics

In this sub-section we apply the traditional backward looking approach to model short run wages and prices dynamics through error correction mechanisms. For that purpose, we regress the first difference of prices and wages on their own lags, the present and past variation of their explanatory factors and the residuals calculated in the last sub-section. The significance of this last variable constitutes an additional test for the cointegration of the variables in levels. In the estimation we have dropped all the variables that were not significant, and we have imposed a new constraint: dynamic homogeneity. This implies that the coefficients of the nominal variables on the right hand side of the equations must add up to one, simply to avoid a permanent trade-off between inflation and long-term unemployment. The two dynamic specifications were jointly estimated and the main results are in Table 5.3.

Firstly, it should be noted that the two error correction mechanisms (resp and resw, respectively) are significant (using the critical values calculated in Banerjee et al. [1998]), negative and lower than unity in absolute terms, confirming the stationarity of the residuals generated in the last sub-section. Besides, the dynamic homogeneity condition was not rejected by data at standard levels of significance. The coefficient for the error correction mechanism in the wage equation was higher (in absolute terms) than in the price equations, meaning that prices are less flexible than wages. The drawback lies in the very complicated lag structure estimated for the two equations, which implies a strong overreaction in the short run.

### 5.4. A forward looking estimation of price and wage inflation

In this section we try to estimate short-run movements in price and wages from an alternative perspective. In particular, in the previous section both wage and price inflation were considered as backward looking variables, so firms and workers look only at previous period values in order to set the new contracts. Nevertheless, since the work of Taylor (1980) it is well-known the importance of both backward and forward looking behavior in price and wage setting has been acknowledged. Moreover, a number of recent papers have stressed the importance of those forward-looking mechanisms in shaping the response of inflation and output to demand disturbances. Thus, works by Furher and Moore (1995) and recently by Galí and Gertler (1999) have put forward the importance of those mechanisms for explaining inflation dynamics in the US. More importantly, the latter paper tries to go one step further deriving the New Phillips curve through explicit microfoundations. Along this new line of research recent works by Kim (1998), Erceg, Henderson and Levin (1999) and Huang and Liu (1999) develop general equilibrium models emphasizing the importance of sticky wages. Although some effort has been made in the analysis of the relative importance of the backward and forward looking components of price inflation, not much empirical evidence appears in the analysis of wage inflation dynamics. This section tries to draw together both pieces of the evidence for Spain.

#### 5.4.1. Price Setting

As shown in the above-mentioned papers, price setting can be characterized through an equation for inflation dynamics as follows[25]:

$$\Delta p_t = bE_t \Delta p_{t+1} - l_p m_{p_t} \qquad [12]$$

[25] See Appendix 5 for a more detailed derivation of the price inflation equation using a forward-looking framework.

where $\mu_p$ represents the firm mark-up. This expression is the so-called New -Keynesian Phillips curve. One of its main characteristics is that it gives a forward looking character to inflation. In particular, solving forward expression [12] current inflation is a function of the present discounted value of the future mark-ups. Higher future mark-ups (i.e. lower marginal costs) reduce current inflation. This specification does not allow for the existence of sticky inflation, something that constitutes a stylized fact in most economies (see, Fuhrer and Moore (1995) for the US and Coenen and Wieland (1999) for Europe).

In order to allow for that, we consider that the previous forward looking price setup only affects a fraction of firms in the economy, while the rest of firms have a backward looking behavior setting current prices in terms of the past prices. Under such circumstances, the Phillips curve takes the following form:

$$\Delta p_t = g_f^p E_t \Delta p_{t+1} + g_b^p \Delta p_{t-1} - l_p m_{p_t} \quad [13]$$

### 5.4.2. Wage Setting

Let us assume that in the economy there is a continuum of workers. Each worker is a monopolistic competitor supplying a differentiated labor service. Following Erceg, Henderson and Levin (1999) we consider that workers set wages in staggered contracts. As in the Calvo model for price adjustment, the workers are allowed to reset their wage contract with probability (1-$q_w$). As in the price setting framework, wage inflation dynamics can be described through the following equation:

$$\Delta w_t = b E_t \Delta w_{t+1} - l_w m_{wt} \quad [14]$$

where $\mu_w$ represents the wage mark-up, i.e. it proxies, given the monopoly power of workers, the differences between the marginal rate of substitution and the real wage, taking as given the future wage inflation. Thus, wage inflation is a function of future wage mark-ups. In other words, high wage inflation today anticipates future lower wage mark-ups. Again in order to allow for stickiness in wage inflation we consider that a fraction of workers are forward looking while the rest set wages looking at past wages. Thus, the wage inflation equation mimics that of prices. Formally, we have it that:

$$\Delta w_t = g_f^w E_t \Delta w_{t+1} + g_b^w \Delta w_{t-1} - l_w m_{wt} \quad [15]$$

Equations [13] and [15] constitute the baseline for our estimates.

### 5.4.3. Results

The results for the estimates of price and wage equations (expressions [13] and [15]) are displayed in Tables 5.4 and 5.5, respectively. Several comments of interest are in order. First, notice the importance of mark-ups in shaping inflation dynamics. Moreover, the point estimates are very low but significant. This result suggests a very low response of wages and prices to real conditions, something related to the existence of significant real rigidities. Second, we find significant lag inflation in the equations but also the forward-looking component is very important. Actually, it is not possible to reject that both coefficients are equal. In any case, the backward looking component seems slightly higher in the wage equations. Finally, the overidentifying restrictions are not rejected at the usual significance level, and, furthermore, there are no significant signs of dynamic correlation in the residuals.

## 6. Conclusions: A comparative analysis of different NAIRU estimates

The NAIRU concept, as an indicator of the structural component of the unemployment rate, is an appealing theoretical concept since it provides a direct link between two of the ultimate targets of macroeconomic policy, namely inflation and unemployment. However, its usefulness for policy purposes is not uncontroversial. The most obvious problem associated with the NAIRU arises from the fact that it must be estimated since it is not observed. Alternative methodologies for measuring the NAIRU lead to important divergences in the point estimates. Furthermore, there is usually a wide confidence interval associated to with of these point estimates. These conventional results raise serious doubts about the usefulness of the NAIRU for the design of macroeconomic policies.

This paper has addressed the issue of measuring the NAIRU in the Spanish economy. We have implemented some of the procedures proposed in the literature to estimate the NAIRU, describing their advantages and disadvantages. To conclude it is worth exploring comparing the different outcomes, not only to discriminate among them, but also to provide an illustration of the uncertainty surrounding the NAIRU estimates. Besides, we compare our estimates to NAWRU calculated by the OECD, which represents a variant of the Phillips curve approach[26]. As it could be seen in Table 6.1, all of our NAIRU estimates show a time-pattern in these five-year sub-periods that is quite similar to the observed unemployment, the TVP NAIRU being the only exception. Provided that the sub-periods correspond to the different recession-expansion cycles of the Spanish economy, a hysteresis component seems to be present.

[26] See OECD (1996).

In the first sub-period (1981-1985) all the NAIRU estimates seem to rise slightly below the increase in observed unemployment. The difference in the lower bound (OECD NAWRU) and the upper bound (TVP NAIRU) is slightly above one percentage point. Over the second half of the eighties there was a decrease in observed unemployment that was only followed by the Price-Wage NAIRU. The other measures of the NAIRU displayed upward trends with different slopes. This is the sub-period with the sharpest discrepancies among the different methods in the changes in the NAIRU. Over the first half of the nineties there is clear evidence that most of the increase in observed unemployment was a cyclical phenomenon: all of the NAIRU went up but by a smaller amount. Finally, in the second half of the nineties the decrease in the NAIRU was quite significant and, in the case of the Price-Wage equations, higher than in observed unemployment. All of our estimates provide a positive sign for the unemployment gap for most of this sub-period, reflecting the absence of inflationary pressures. In 1999, the width of the NAIRU estimates gives an additional indication of the uncertainty surrounding the measurement of this concept.

Our analysis shows that different approaches to measure the NAIRU provide significantly different point estimates. Moreover, whenever some measure of the precision of the estimate is available (Phillips-curve based estimates and SVAR estimates), the degree of uncertainty is non-negligible. Thus, our main conclusion is that the usefulness of the NAIRU concept as a general guideline for discussing and analyzing macroeconomic policy is very limited, given the current state of economic research on this area. Two additional conclusions may be summarized as follows. First, all the NAIRU estimates display an upsurge between 1981 and 1985, and a drop during the last cyclical upturn that has closely followed the decline in the observed unemployment rate. Second, the results of the structural approach point to three factors driving the evolution of the NAIRU over the sample period: price mark-ups, the replacement ratio and changes in the tax system.

# TABLES

# AND

# FIGURES

## Table 2.1. PREDICTIVE POWER OF DEVIATIONS FROM UNIVARIATE NAIRU

$$p - p_{t-1} = b_1 (u_{t-1} - u^*_{t-1}) + b_2 (u_{t-2} - u^*_{t-2}) + b_3 (u_{t-3} - u^*_{t-3}) + b_4 (u_{t-4} - u^*_{t-4}) + C(L)\Delta p_{t-1}$$

$$H_0^1 : b_1 = b_2 = b_3 = b_4 = 0 ;\ H_0^2 : b_1 + b_2 + b_3 + b_4 = 0 ;$$

| | | CPI | Underlying CPI | Underlying CPI without indirect taxes | GDP deflator | Wages (ES) | Wages (QNA) |
|---|---|---|---|---|---|---|---|
| HP | $H_0^1$ | 0.77 | 0.59 | 0.87 | 0.96 | 0.79 | 0.02 |
| | $H_0^2$ | 0.86 | 0.66 | 0.82 | 0.48 | 0.98 | 0.57 |
| BP | $H_0^1$ | 0.78 | 0.56 | 0.84 | 0.97 | 0.78 | 0.01 |
| | $H_0^2$ | 0.73 | 0.56 | 0.68 | 0.60 | 0.78 | 0.36 |

Notes: These figures correspond to the p-values of the specified hypothesis.

## Table 2.2. PREDICTIVE POWER OF DEVIATIONS FROM UNIVARIATE NAIRU

$$p_t - p_t^e = b_1 (u_{t-1} - u^*_{t-1}) + b_2 (u_{t-2} - u^*_{t-2}) + b_3 (u_{t-3} - u^*_{t-3}) + b_4 (u_{t-4} - u^*_{t-4}) + C(L)(p_{t-1} - p^e_{t-1})$$

$$H_0^1 : b_1 = b_2 = b_3 = b_4 = 0 ;\ H_0^2 : b_1 + b_2 + b_3 + b_4 = 0 ;$$

| | | CPI | Underlying CPI | Underlying CPI without indirect taxes | GDP deflator | Wages (ES) | Wages (QNA) |
|---|---|---|---|---|---|---|---|
| HP | $H_0^1$ | 0.85 | 0.70 | 0.43 | 0.98 | 0.55 | 0.40 |
| | $H_0^2$ | 0.96 | 0.48 | 0.37 | 0.77 | 0.62 | 0.64 |
| BP | $H_0^1$ | 0.85 | 0.63 | 0.42 | 0.99 | 0.43 | 0.31 |
| | $H_0^2$ | 0.74 | 0.34 | 0.36 | 0.99 | 0.31 | 0.33 |

Notes: See previous table.

Table 3.1. ESTIMATES OF THE NAIRU BASED ON THE PHILLIPS-CURVE

| | (a) | (b) | (c) |
|---|---|---|---|
| NAIRU model | Constant NAIRU | Break NAIRU | Spline NAIRU |
| B (1) | -0.116 | -0.183 | 0.280 |
| | (0.055) | (0.098) | (0.236) |
| Estimates of NAIRU | | | |
| 1982:1 | 17.98 | 14.95 | 14.00 |
| | (1.48) | (2.41) | (2.33) |
| 1986:1 | 17.98 | 19.37 | 23.84 |
| | (1.48) | (1.32) | (3.53) |
| 1991:2 | 17.98 | 19.37 | 15.70 |
| | (1.48) | (1.32) | (1.88) |
| 1994:1 | 17.98 | 19.37 | 21.49 |
| | (1.48) | (1.32) | (1.25) |
| 1999:3 | 17.98 | 19.37 | 11.58 |
| | (1.48) | (1.32) | (4.72) |
| $R^2$ | 0.816 | 0.818 | 0.739 |

Notes: Standard errors in brackets. These standard errors are computed using the "delta method" as the NAIRU is obtained as a non-linear function of the regression coefficients.

Table 3.2. TIME-VARYING PARAMETER ESTIMATES OF NAIRU

| | (a) | (b) | (c) |
|---|---|---|---|
| Smoothness parameter ($\sigma_\eta$) | $\sigma_\eta$=0.01 | $\sigma_\eta$=0.02 | $\sigma_\eta$=0.03 |
| B (1) | -0.035 | -0.126 | -0.074 |
| | (0.019) | (0.034) | (0.018) |
| Estimates of NAIRU | | | |
| 1982:1 | 16.88 | 15.27 | 18.40 |
| 1986:1 | 18.63 | 22.80 | 25.76 |
| 1991:2 | 19.90 | 19.67 | 21.25 |
| 1994:1 | 19.19 | 21.19 | 21.70 |
| 1999:3 | 17.49 | 19.21 | 18.21 |
| $R^2$ | 0.821 | 0.846 | 0.853 |

**Table 4.1. PREDICTIVE POWER OF DEVIATIONS FROM SVAR (partial hysteresis) NAIRU**

$$p - p_{t-1} = b_1 (u_{t-1} - u^*_{t-1}) + b_2 (u_{t-2} - u^*_{t-2}) + b_3 (u_{t-3} - u^*_{t-3}) + b_4 (u_{t-4} - u^*_{t-4}) + C(L)\Delta p_{t-1}$$

$$H^1_0 : b_1 = b_2 = b_3 = b_4 = 0 ;\ H^2_0 : b_1 + b_2 + b_3 + b_4 = 0 ;$$

| | Cyclical component | CPI | Underlying CPI | Underlying CPI without indirect taxes | GDP deflator | Wages (ES) | Wages (QNA) |
|---|---|---|---|---|---|---|---|
| $H^1_0$ | 0.00 | 0.54 | 0.02 | 0.16 | 0.28 | 0.80 | 0.01 |
| $H^2_0$ | 0.00 | 0.22 | 0.13 | 0.16 | 0.54 | 0.45 | 0.50 |

Notes: These figures correspond to the p-values of the specified hypothesis. The cyclical component corresponds to that estimated from the SVAR (see Figure 4.1).

**Table 5.1. LONG-RUN ESTIMATES FOR THE EQUATIONS OF PRICES AND WAGES**

| | WHOLE ECONOMY | | PRIVATE SECTOR | |
|---|---|---|---|---|
| | Price Equation | Wage Equation | Price Equation | Wage Equation |
| $\alpha$ | 0.658* | 0.658* | 0.648* | 0.648* |
| $\beta$ | 0.001 | 0.001 | 0.002 | 0.002 |
| $\gamma_1$ | 0.110 | - | 0.110 | - |
| $c_1$ (U) | - | -0.137 | - | -0.200 |
| $c_3$ (b) | - | 0.086 | - | 0.075 |
| $c_5$ ($t_1$) | - | 0.521 | - | 0.744 |
| $c_6$ ($t_2$) | - | 0.335 | - | - |
| DW | 0.158 | 0.249 | 0.171 | 0.257 |
| $\sigma$*100 | 1.120 | 0.805 | 1.204 | 0.766 |
| ADF | -2.273 | -2.573 | -3.720 | -4.030 |

Notes: * Restricted coefficient; DW: Durbin-Watson statistic; σ: standard deviation of the residuals; ADF: augmented Dickey-Fuller statistic.

**Table 5.2. PREDICTIVE POWER OF DEVIATIONS FROM WAGE AND PRICE EQUATIONS NAIRU**

$$p - p_{t-1} = b_1\left(u_{t-1} - u^*_{t-1}\right) + b_2\left(u_{t-2} - u^*_{t-2}\right) + b_3\left(u_{t-3} - u^*_{t-3}\right) + b_4\left(u_{t-4} - u^*_{t-4}\right) + C(L)\Delta p_{t-1}$$

$$H_0^1 : b_1 = b_2 = b_3 = b_4 = 0 ;\; H_0^2 : b_1 + b_2 + b_3 + b_4 = 0 ;$$

| | CPI | Underlying CPI | Underlying CPI without indirect taxes | GDP deflator | Wages (ES) | Wages (QNA) |
|---|---|---|---|---|---|---|
| $H_0^1$ | 0.57 | 0.14 | 0.19 | 0.88 | 0.36 | 0.03 |
| $H_0^2$ | 0.53 | 0.97 | 0.99 | 0.91 | 0.65 | 0.24 |

Notes: These figures correspond to the p-values of the specified hypothesis.

## Table 5.3. BACKWARD-LOOKING ESTIMATES FOR THE DYNAMIC EQUATIONS OF PRICES AND WAGES

| | Price Equation | Wage Equation |
|---|---|---|
| $\Delta p$ | - | 0.417 |
| | | (5.22) |
| $\Delta p_{-1}$ | 1.593 | -0.377* |
| | (22.17) | (-) |
| $\Delta p_{-2}$ | -0.750 | - |
| | (-8.75) | |
| $\Delta p_{-4}$ | 0.189 | - |
| | (4.60) | |
| $\Delta w$ | 0.487 | - |
| | (4.65) | |
| $\Delta w_{-1}$ | -0.293 | 1.121 |
| | (-4.25) | (14.14) |
| $\Delta w_{-2}$ | 0.294 | -0.336 |
| | (4.54) | (-3.57) |
| $\Delta w_{-3}$ | -0.537 | - |
| | (-5.16) | |
| $\Delta w_{-4}$ | - | 0.175 |
| | | (3.52) |
| $\Delta p^*_{-3}$ | 0.017* | - |
| | (-) | |
| $\Delta u_{-3}$ | - | -0.091 |
| | | (-3.06) |
| $resp_{-1}$ | -0.051 | - |
| | (-3.36) | |
| $resw_{-1}$ | - | -0.108 |
| | | (-4.77) |
| $R^2$ | 0.99 | 0.94 |
| $\sigma$*100 | 0.11 | 0.13 |
| DW | 1.78 | 1.71 |
| CORR(1) | 0.64 | 1.37 |
| | [0.42] | [0.24] |
| CORR(4) | 1.02 | 0.54 |
| | [0.40] | [0.71] |
| ARCH(4) | 0.48 | 0.85 |
| | [0.74] | [0.50] |
| BJ(2) | 3.24 | 0.19 |
| | [0.20] | [0.91] |
| DH(1) | 3.12 | 2.54 |
| | [0.08] | [0.11] |

Notes: See previous table. CORR(i) is the order i autocorrelation residual test, distributed as an F(i,df); ARCH(i) is the heteroskedasticity type ARCH residual test, distributed as a F(i,fd); BJ(2) is the normality test of the residuals, distributed as a $\chi^2(2)$; HD(1) is the dynamic homogeneity test, distributed as a F(1,fd). t-values in parenthesis; p-values in brackets.

**Table 5.4. ESTIMATES OF THE HYBRID PRICE EQUATION**

| $\gamma^p_b$ | $\gamma^p_f$ | $\lambda_p$ | DW | Overidentifying Restrictions Test (DF) |
|---|---|---|---|---|
| 0.517 | 0.482 | 0.033 | 1.78 | 6.63 (9) |
| (0.016) | (0.015) | (0.006) | | |

**Table 5.5. ESTIMATES OF THE HYBRID WAGE EQUATION**

| $\gamma^W_b$ | $\gamma^W_f$ | $\lambda_W$ | DW | Overidentifying Restrictions Test (DF) |
|---|---|---|---|---|
| 0.549 | 0.451 | 0.031 | 2.28 | 6.51 (9) |
| (0.028) | (0.026) | (0.009) | | |

**Note**: Standard errors are in parenthesis. The test of overidentifying restrictions is distributed as $\chi^2$ a with DF degrees of freedom. GMM estimation using the following instruments: four lags of imported price inflation, wage inflation and the long-term equilibrium. The price equation includes a dummy for the period 84:4 to 85:2. The wage equation includes a dummy taking value 1 and -1 in 1996:1 and 1996:4, respectively. Although not reported, the equations include a constant term.

**Table 6.1. OBSERVED UNEMPLOYMENT AND ALTERNATIVE ESTIMATIONS OF THE NAIRU**

Differences between first and last period

| | Observed Unemployment | Phillips Curve TVP NAIRU | SVAR Partial Hysteresis NAIRU | Price-Wage Equations NAIRU | OECD NAWRU |
|---|---|---|---|---|---|
| 1981-1985 | 7.4 | 7.0 | 6.7 | 6.7 | 5.8 |
| 1985-1991 | -5.1 | 0.6 | 2.5 | -0.7 | 1.6 |
| 1991-1994 | 7.8 | 0.4 | 1.9 | 1.4 | 0.8 |
| 1994-1999 | -7.9 | -1.8 | -7.2 | -8.3 | -2.0* |
| Level in 1999 | 16.0 | 18.9 | 16.0 | 13.5 | 18.8** |

*This difference was calculated using data only to 1998; **Level in 1998.

**FIGURE 3.1. UNCERTANTY ON NAIRU ESTIMATES. Spline Model**

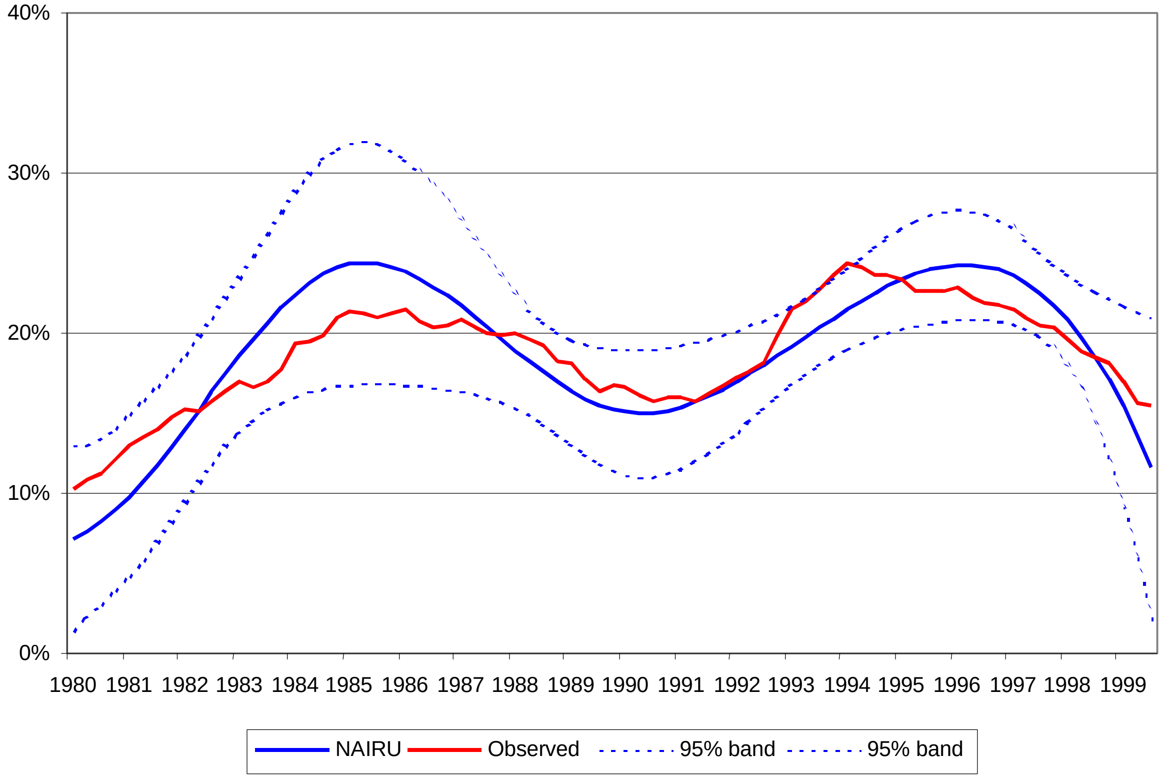



**FIGURE 3.2. TVP NAIRU. Alternative standard deviations**

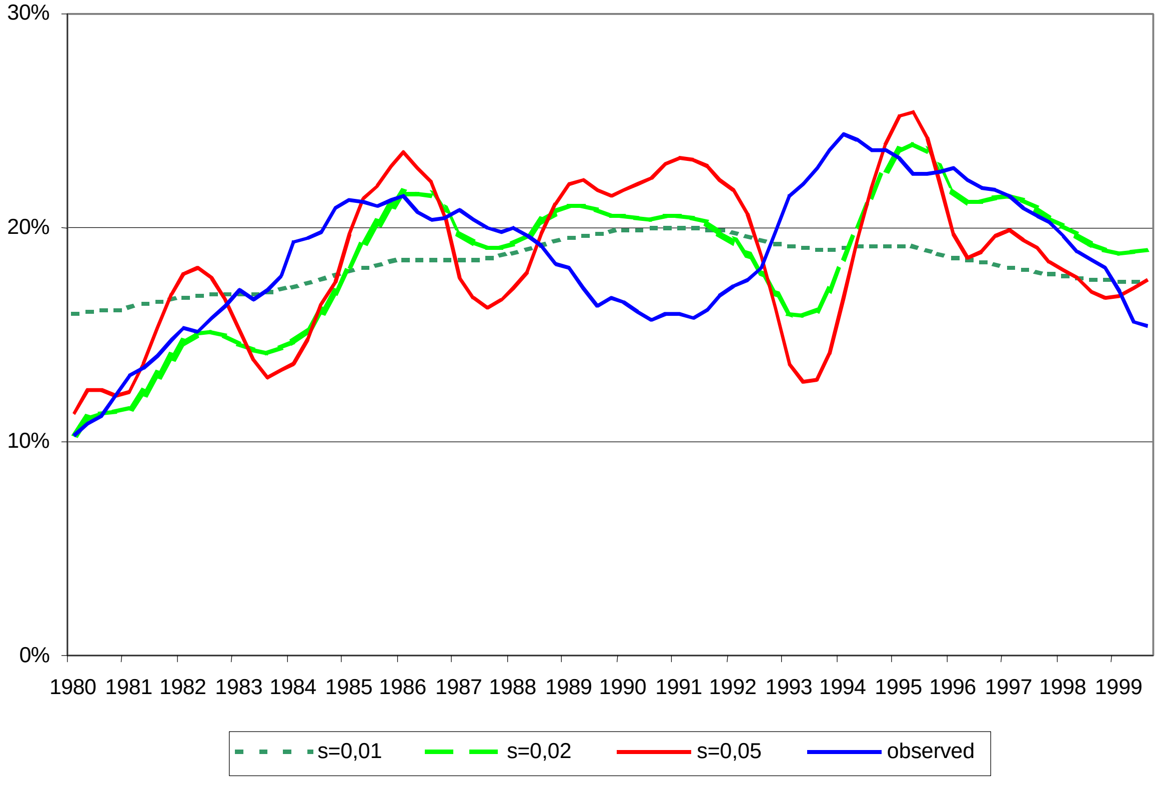
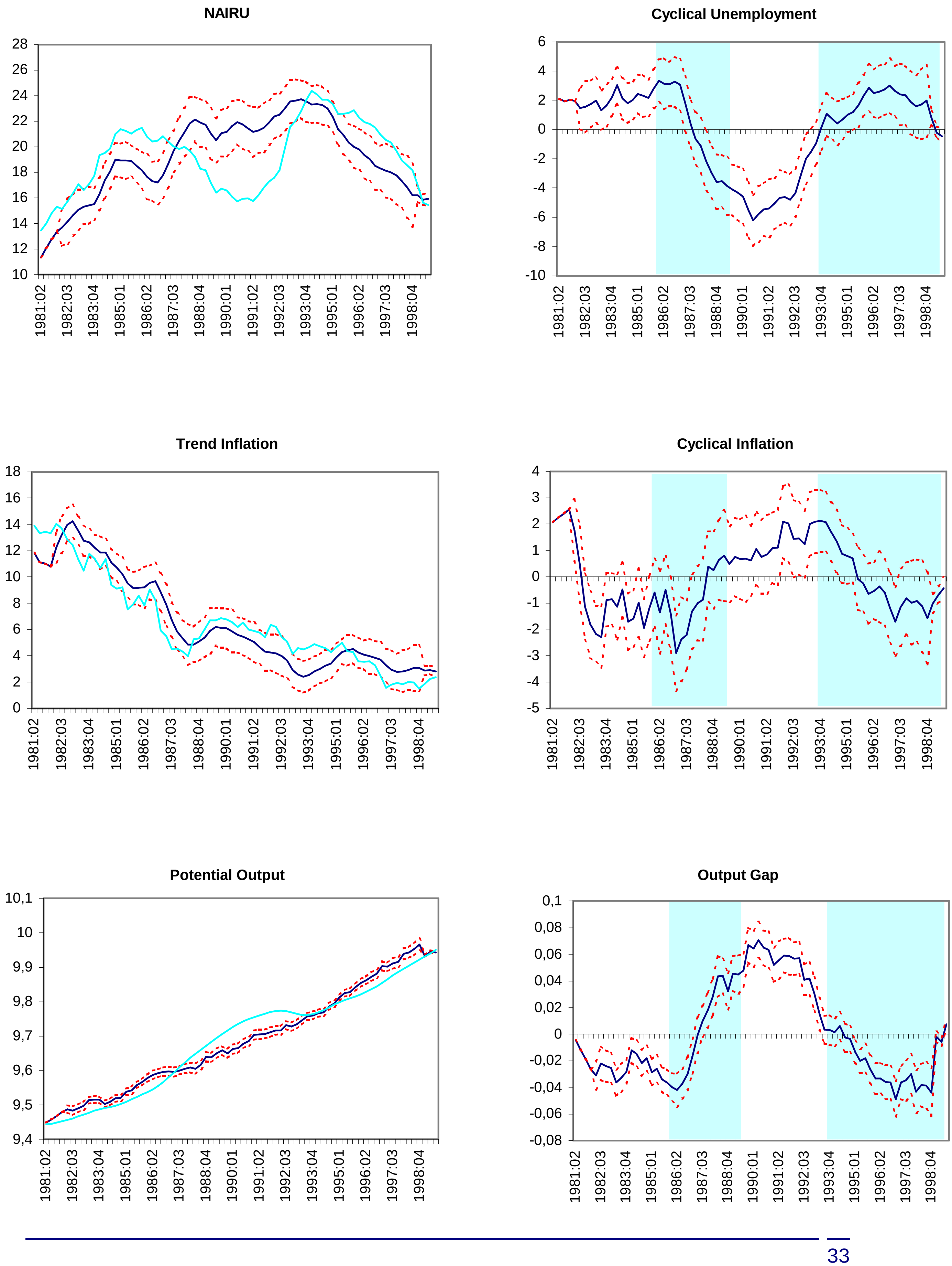
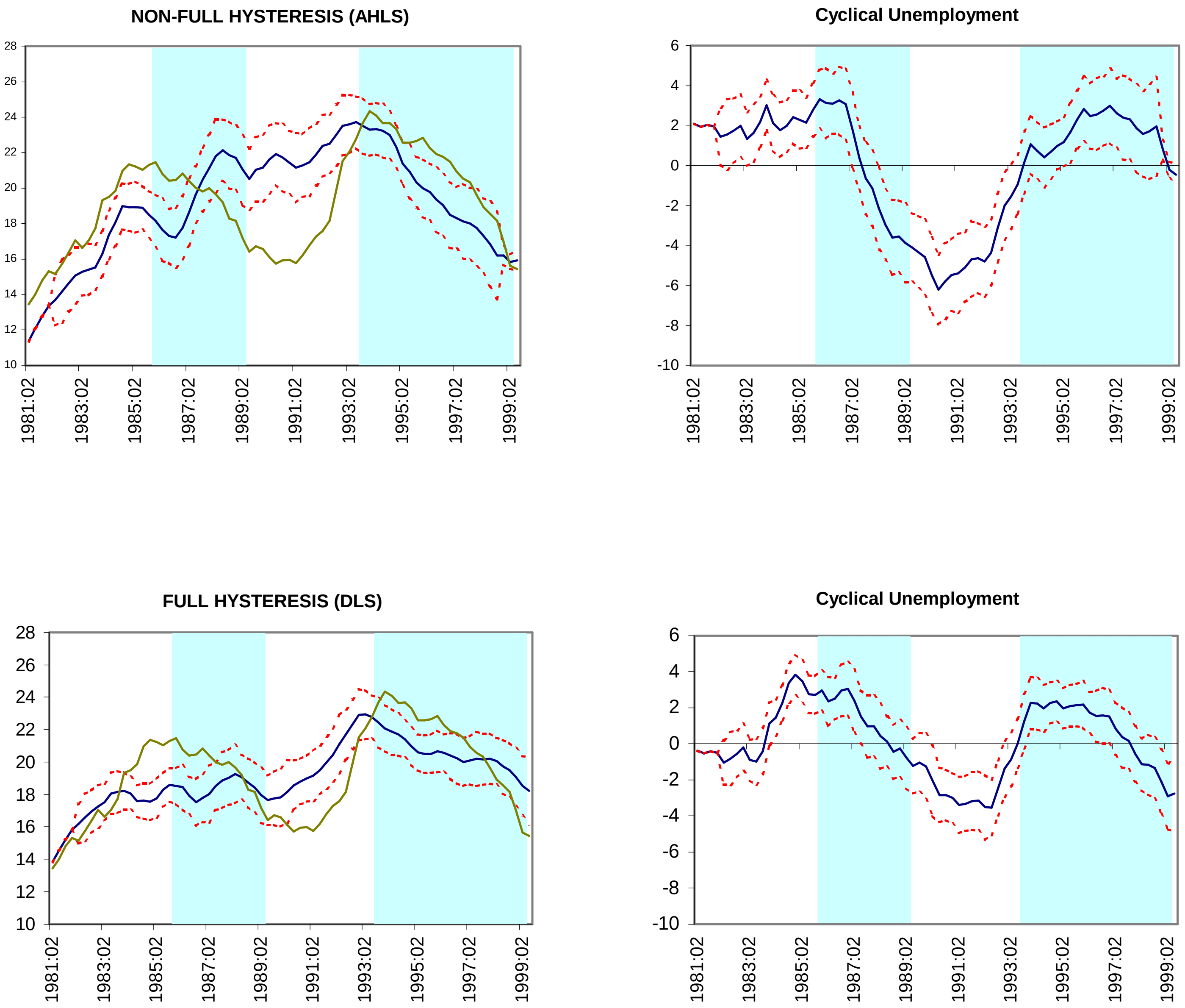


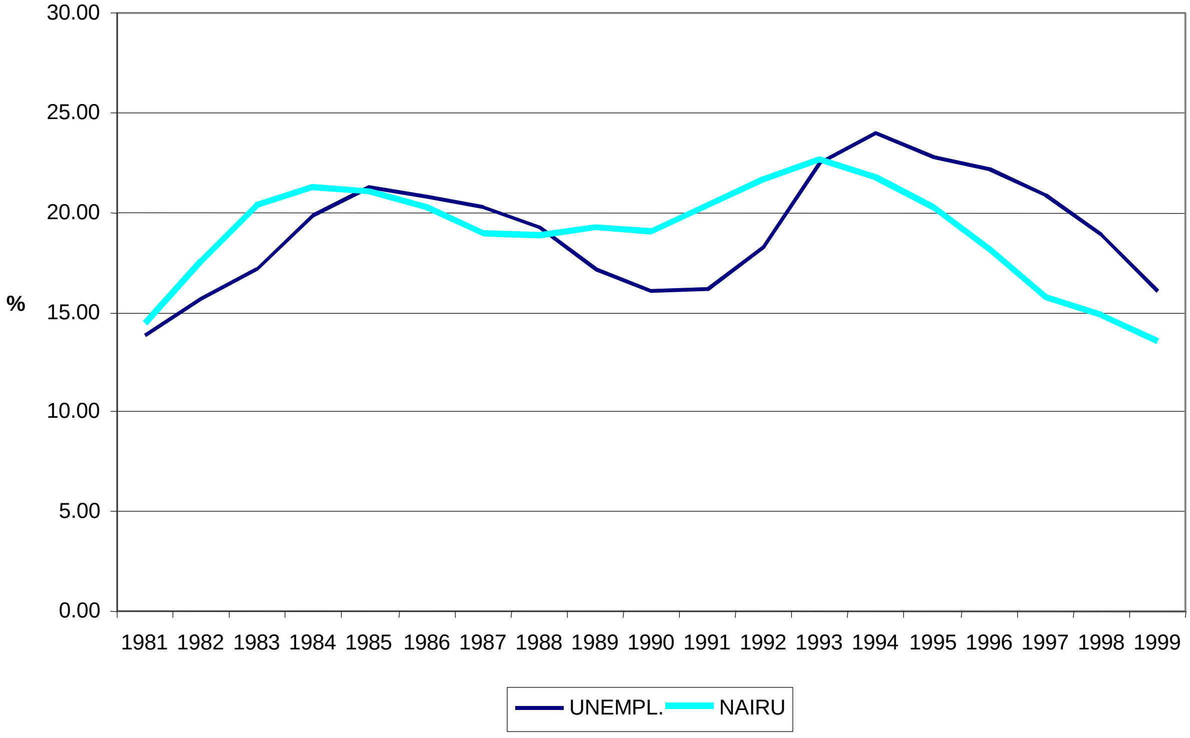
FIGURE 4.1. TREND-CYCLE DECOMPOSITION



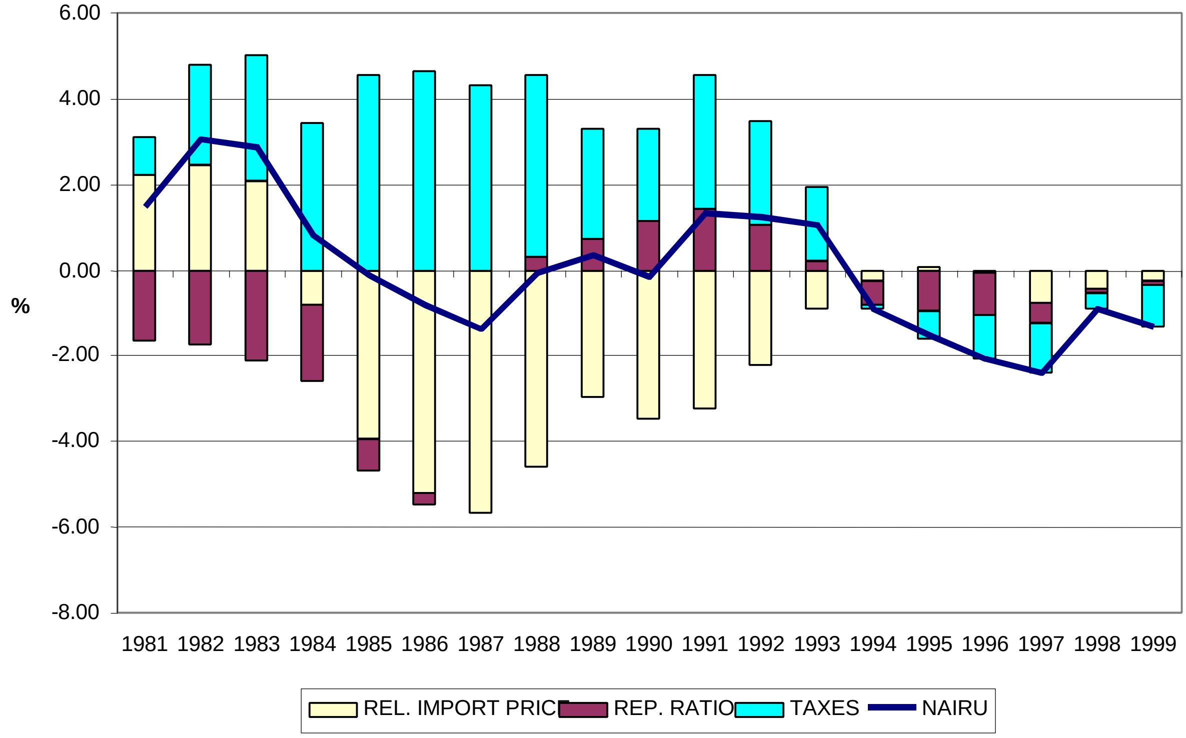
## FIGURE 4.2. ALTERNATIVE NAIRU IDENTIFICATIONS



## FIGURE 5.1. OBSERVED UNEMPLOYMENT AND NAIRU




## FIGURE 5.2. CONTRIBUTION TO NAIRU VARIATION



# APPENDICES

## APPENDIX 1. THE DATA BASE AND UNIT ROOT TESTS

The database used in this document has been constructed combining information from many sources. In the case of National Accounts, on an ESA 95 basis the information was only available from 1995, so we enlarge the timeseries to 1980 using two other National Accounts bases (1986 and 1980). The procedure to do this tries to keep growth rates in line with the old ones, but makes some adjustments in order to satisfy the accounting identities[27]. For some variables in the old National Accounts there was no quarterly information, so we had to interpolate them using indicators[28]. In other sources we also made some adjustments, simply to avoid their methodological changes.

— **Unemployment and employment**

- Unemployment. Taken from the Labour Force Survey, it is consistent with the ILO definition. The figures were adjusted for changes in the Census figures and, prior to 1987, for changes in the definition of labour force, employment and so on.

- Demographically Adjusted Unemployment. It is elaborated assuming that the distribution of labour force in terms of sex and age is unchanged from the 1997 structure.

- Long-Term Unemployment Ratio: People in unemployment for more than one year, taken from the Labour force Population Survey.

- Temporary Ratio. Temporary workers taken from the Labour Force Survey. Prior to 1987 data were generated using information from the Banco de España Central Balance Sheet Office.

- Wage Earners. Corresponds to equivalent full-time dependent employment taken from National Accounts. Prior to 1995 the figures were interpolated using the corresponding series from the Labour Force Survey.

- Wage Earners in the private sector. Corresponds to equivalent full-time dependent employment in the market sectors taken from National Accounts. Prior to 1995 the figures were interpolated using the corresponding series from the Labour Force Survey.

[27] The series we are using correspond to the trend-cycle signal, because on ESA 79 definitions and on a quarterly basis they were the only ones available.

[28] The interpolation procedure used was the Chow-Lin method.

- Total Employment. Corresponds to equivalent full-time employment taken from National Accounts. Prior to 1995 the figures were interpolated using the corresponding series from the Labour Force Survey.

- Total Employment in the private sector. Corresponds to equivalent full-time employment in the tradable sectors taken from National Accounts. Prior to 1995 the figures were interpolated using the corresponding series from the Labour Force Survey.

— **Prices**

- Consumer Price Index (CPI). Official series for the CPI, base 1992.

- Underlying CPI. CPI minus non-processed food and energy prices.

- Underlying CPI excluding changes in Indirect Taxation. Underlying CPI minus the legal changes in indirect taxation.

- Food Prices. Corresponds to the non-processed food component of the CPI.

- Energy Prices. Corresponds to unit value indices for energy imports from Customs statistics.

- Import prices. The implicit deflator for imports of goods taken from National Accounts.

- Non-Energetic Import Prices. Calculated from the two previous definitions.

- GDP Deflator. The implicit deflator for GDP in National Accounts

- GDP Deflator net of Indirect Taxes. Calculated by dividing the GDP deflator by one plus the tax rate. The tax rate was elaborated by dividing net taxes from National Accounts by nominal GDP. Before 1995 the quarterly figures for net taxes were interpolated using information from tax collection.

- GVA Deflator in the Private Sector. The implicit deflator for gross value added in the tradable sectors from National Accounts.

— **Wages**

- Wage per employee. Corresponds to total payments per employee from the Wage Survey.

- Compensation per employee. Calculated dividing total compensation of employees from National Accounts by wage-earners. Before 1995 the indicator used for interpolation was the previous one.

- Compensation per employee in the tradable sector. Calculated by dividing total compensation of employees in the tradable sectors taken from National Accounts by wage-earners in the tradable sectors. Before 1995 the indicator used for interpolation was compensation per employee taken from the Wage Survey.

— **Production**

- GDP at market prices. GDP at constant prices taken from National Accounts.

- GDP at Factor Prices. Defined as nominal GDP at factor prices from National Accounts divided by the GDP Deflator net of indirect taxes.

- GVA of the private sector. It is the gross value added at constant prices in the tradable sectors from National Accounts.

— **Other Variables**

- Capital Stock. Taken from the BBV foundation regional database. It was interpolated combining information from quarterly real investment and yearly constant scrapping rates.

- Capital Stock in the Private Sector. Taken from the BBV foundation regional database. It was interpolated combining information from quarterly real private investment and yearly constant scrapping rates.

- Social Security Contributions Tax Rates. Calculated by dividing contributions of wage earners paid by themselves or by the employer on net wages of employees. The contributions were interpolated using information from tax collection.

- Income Tax Rate. Calculated by dividing direct taxes paid by households by disposable income of households plus direct taxes paid by households. Quarterly direct taxes paid by households were interpolated using information from tax collection.

- Indirect Tax Rate. Defined as indirect taxes net of subsidies on nominal private consumption plus residential investment minus own taxes.

- Replacement Ratio. Defined as the ratio of unemployment benefits by eligible unemployment to compensation per employee (all of them net of contributions to Social Security and income taxation), multiplied by the coverage ratio (defined as the ratio of people receiving unemployment benefits to registered unemployment).

- Vacancy Ratio. Number of vacancies divided by unemployment. The number of vacancies corresponds to unmet job offers in the INEM.

- Mismatch Index: The standard deviation of unemployment and vacancies by occupational category (see pp. 326 in Layard, Nickell and Jackman [1991]).

- Ratio of People involved in Strikes. People involved in strikes from labour conflict statistics on wage earners.

In Table A.1.1 we have performed the ADF test for the variables described previously. The first three columns consider the variables in first differences, so the null corresponds to integration of order two; in the last three columns the variables are in levels, so the null is integration of order one. As it can be seen, most of the variables reject the I(2) hypothesis, but there are some exceptions. On the real side, GDP at market prices and at factor cost seem to need a second difference to be stationary, a common conclusion in the empirical analysis for Spain solved using truncated trends; as long as the value added in the private sector is a I(1) variable, we think that the behaviour of the public sector in our particular sample period could be responsible. Something similar happens with total employment, it being a I(1) variable for the private sector but only at 10% for the private sector. Finally, capital stocks are also in the region of uncertainty, not surprisingly provided the way they are constructed. On the nominal side, we have some prices and wages clearly rejecting the I(2) hypothesis but this is not the case for underlying inflation or compensation per employee.

When the variables are considered in levels we accept the I(1) hypothesis for most of the variables except for the unemployment rate (with some doubts), the percentage of long-term unemployment, the mismatch index and the percentage of people involved in strikes. It is perhaps surprising to find that variables such as the temporary ratio and the different tax rates are integrated of order one, but it should be remembered that temporary contracts showed a very marked increase after the change in legislation in 1983, and taxes departed from a very low level.

**Table A.1.1. UNIT ROOT TESTS**

| | First Differences | | | Levels | | |
|---|---|---|---|---|---|---|
| | Number of lags | Deterministic Component | ADF Test | Number of lags | Deterministic Component | ADF Test |
| Observed Unemployment | 0 | c,s | -3.31* | 4 | c,s | -2.72** |
| Demog. Adj. Unemployment | 0 | c,s | -3.25* | 4 | c,s | -2.57 |
| Long-Term Unemployment Ratio | 0 | c,s | -6.85* | 4 | c,s | -3.27* |
| Temporary Ratio | 1 | c,s | -3.17* | 2 | c,s | -1.20 |
| Wage Earners | 1 | - | -1.80** | 2 | c,t | -3.20 |
| Wage Earners, Private Sector | 1 | - | -1.82** | 2 | c,t | -2.89 |
| Total Employment | 1 | - | -1.88** | 2 | c,t | -3.21 |
| Total Employment, Private Sector | 1 | - | -2.04* | 2 | c,t | -2.61 |
| Consumer Price Index (CPI) | 3 | s | -2.33* | 4 | c,s | -2.72** |
| Underlying CPI | 2 | s | -1.94** | 4 | c,s | -2.73** |
| Underlying CPI Net Indirect Taxes | 3 | s | -1.94** | 4 | c,s,t | -2.95 |
| Food Prices | 3 | c,s | -2.90* | 4 | c,s | -2.72** |
| Energy Unit Value Index | 4 | - | -6.44* | 2 | - | -1.57 |
| Import Deflator | 2 | - | -3.35* | 3 | c,t | -2.96 |
| Non-Energy Import Prices | 4 | c | -4.56* | 4 | c,t | -2.98 |
| GDP Deflator | 4 | - | -1.98* | 2 | c,t | -1.45 |
| GDP Deflator Net Indirect Taxes | 4 | - | -2.19* | 2 | c,t | -1.03 |
| GVA Deflator Private Sector | 4 | - | -2.08* | 2 | c,t | -2.28 |
| Wage per Employee | 4 | s | -2.47* | 2 | c,s,t | -1.42 |
| Compensation per Employee | 3 | - | -1.85** | 4 | c,t | -1.32 |
| Compens. per Emp. Private Sector | 2 | - | -2.32* | 2 | c | -2.39 |
| GDP at Market Prices | 3 | c | -2.05 | 4 | c,t | -3.03 |
| GDP at Factor Costs | 3 | c | -2.05 | 4 | c,t | -3.03 |
| GVA Private Sector | 1 | c | -3.10* | 4 | c,t | -2.56 |
| Capital Stock | 2 | c | -2.71** | 3 | c,t | -3.13 |
| Capital Stock Private Sector | 4 | c | -2.60** | 3 | c,t | -3.14 |
| Social Contribution Tax Rate | 4 | - | -2.35* | 4 | c | -2.26 |
| Income Tax Rate | 4 | - | -2.56* | 2 | c | -1.69 |
| Indirect Tax Rate | 2 | - | -3.00* | 3 | c,t | -2.37 |
| Replacement Ratio | 4 | - | -3.16* | 4 | c | -1.98 |
| Vacancy Ratio | 0 | s | -6.10* | 1 | s,t | -1.53 |
| Mismatch Index | 4 | - | -8.65* | 3 | c,t | -7.24* |
| People Involved in Strikes | 3 | s | -7.65* | 2 | c,s,t | -8.46* |

Notes: * Significant at 5%; ** Significant at 10%; c, constant; s, seasonal; t, trend.

## APPENDIX 2. SENSITIVITY ANALISYS OF THE UNIVARIATE PROCEDURES

In order to investigate the sensitivity of the filters to the selected parameters, we have considered other values for them, implying a greater degree of smoothness of the estimated NAIRU. Thus, for the H-P filter we have used $\lambda_2$=6400 and $\lambda_3$=25600, and for the B-P filter we have widened the window to forty-eight quarters (B-$P_1$) and sixty quarters (B-$P_2$), in both cases with a moving average of forty-eight quarters. The estimated NAIRU shows a milder profile, and, obviously, main discrepancies emerge when there are turning points in the observed unemployment. As it can be seen in tables A.2.1 and A.2.2, the predictive power of the unemployment gap improves when these milder measures of the NAIRU are considered.

Table A.2.1. PREDICTIVE POWER OF DEVIATIONS FROM UNIVARIATE NAIRU. SENSITIVITY ANALISYS

$$p - p_{t-1} = b_1(u_{t-1} - u^*_{t-1}) + b_2(u_{t-2} - u^*_{t-2}) + b_3(u_{t-3} - u^*_{t-3}) + b_4(u_{t-4} - u^*_{t-4}) + C(L)\Delta p_{t-1}$$

$$H^1_0 : b_1 = b_2 = b_3 = b_4 = 0 ;\ H^2_0 : b_1 + b_2 + b_3 + b_4 = 0 ;$$

| | | CPI | Underlying CPI | Underlying CPI without indirect taxes | GDP deflator | Wages (ES) | Wages (QNA) |
|---|---|---|---|---|---|---|---|
| $HP_2$ | $H^1_0$ | 0.63 | 0.50 | 0.79 | 0.99 | 0.76 | 0.01 |
| | $H^2_0$ | 0.44 | 0.36 | 0.55 | 0.88 | 0.76 | 0.45 |
| $HP_3$ | $H^1_0$ | 0.52 | 0.43 | 0.72 | 0.99 | 0.71 | 0.01 |
| | $H^2_0$ | 0.27 | 0.25 | 0.42 | 0.90 | 0.64 | 0.37 |
| $BP_2$ | $H^1_0$ | 0.56 | 0.41 | 0.73 | 0.90 | 0.70 | 0.01 |
| | $H^2_0$ | 0.32 | 0.25 | 0.40 | 0.90 | 0.57 | 0.26 |
| $BP_3$ | $H^1_0$ | 0.43 | 0.36 | 0.66 | 0.99 | 0.61 | 0.01 |
| | $H^2_0$ | 0.20 | 0.19 | 0.34 | 0.78 | 0.58 | 0.27 |

Notes: These figures correspond to the p-values of the specified hypothesis.

Table A.2.2. PREDICTIVE POWER OF DEVIATIONS FROM UNIVARIATE NAIRU. SENSITIVITY ANALISYS

$$p_t - p^e_t = b_1(u_{t-1} - u^*_{t-1}) + b_2(u_{t-2} - u^*_{t-2}) + b_3(u_{t-3} - u^*_{t-3}) + b_4(u_{t-4} - u^*_{t-4}) + C(L)(p_{t-1} - p^e_{t-1})$$

$$H^1_0 : b_1 = b_2 = b_3 = b_4 = 0 ;\ H^2_0 : b_1 + b_2 + b_3 + b_4 = 0 ;$$

| | | CPI | Underlying CPI | Underlying CPI without indirect taxes | GDP deflator | Wages (ES) | Wages (QNA) |
|---|---|---|---|---|---|---|---|
| $HP_2$ | $H^1_0$ | 0.69 | 0.56 | 0.30 | 0.97 | 0.48 | 0.29 |
| | $H^2_0$ | 0.54 | 0.26 | 0.16 | 0.72 | 0.41 | 0.34 |
| $HP_3$ | $H^1_0$ | 0.52 | 0.44 | 0.24 | 0.91 | 0.40 | 0.21 |
| | $H^2_0$ | 0.31 | 0.16 | 0.10 | 0.45 | 0.26 | 0.17 |
| $BP_2$ | $H^1_0$ | 0.65 | 0.42 | 0.27 | 0.90 | 0.33 | 0.19 |
| | $H^2_0$ | 0.43 | 0.16 | 0.13 | 0.45 | 0.20 | 0.15 |
| $BP_3$ | $H^1_0$ | 0.49 | 0.34 | 0.20 | 0.78 | 0.27 | 0.12 |
| | $H^2_0$ | 0.28 | 0.10 | 0.08 | 0.27 | 0.15 | 0.08 |

Notes: See previous table.

## APPENDIX 3. SENSITIVITY ANALYSIS FOR THE PHILLIPS CURVE FRAMEWORK

To investigate the sensitivity of the estimates of the NAIRU based on the Phillips curve framework, presented in section 3, we have conducted a sensitivity analysis. First, we have considered inflation series computed using alternative prices/wages indicators: CPI excluding food and energy, CPI excluding food, energy and taxes, GDP deflator. Second, as an alternative measure of inflation expectations we have considered a recursive AR(4) forecast. The results are displayed in Tables A.3.1 to A.3.3 for the alternative NAIRU models: Constant NAIRU, Break NAIRU and TVP NAIRU. Overall, these results reinforce the conclusion that the NAIRU is imprecisely measured.

Table A.3.1. ESTIMATES OF THE CONSTANT NAIRU MODEL FOR ALTERNATIVE PRICE DEFINITIONS

| Price Definition | Formation of $\pi^e$ | B(1) | NAIRU estimate | $R^2$ |
|---|---|---|---|---|
| CPI | $\pi^e=\pi_{t-1}$ | -0.116<br>(0.055) | 17.98<br>(1.48) | 0.816 |
| CPI | $\pi^e$=ARIMA forecast | -0.032<br>(0.051) | 15.88<br>(6.43) | 0.461 |
| CPI excluding food and energy | $\pi^e=\pi_{t-1}$ | -0.013<br>(0.042) | 20.55<br>(13.95) | 0.688 |
| CPI without taxes, excluding food and energy | $\pi^e=\pi_{t-1}$ | 0.036<br>(0.038) | 17.83<br>(4.35) | 0.649 |
| GDP Deflator | $\pi^e=\pi_{t-1}$ | 0.023<br>(0.013) | 18.61<br>(2.53) | 0.541 |

Notes: Standard errors in brackets (in the estimation of the NAIRU they are from the delta method).

Table A.3.2. ESTIMATES OF THE BREAK NAIRU MODEL FOR ALTERNATIVE PRICE DEFINITIONS

| Price Definition | Formation of $\pi^e$ | B(1) | NAIRU estimate | | $R^2$ |
|---|---|---|---|---|---|
| | | | 1979q3-1984q4 | 1985q1-1999q3 | |
| CPI | $\pi^e=\pi_{t-1}$ | -0.183<br>(0.098) | 14.95<br>(2.41) | 19.37<br>(1.32) | 0.818 |
| CPI | $\pi^e$=ARIMA forecast | -0.092<br>(0.105) | 14.82<br>(5.31) | 18.83<br>(3.24) | 0.490 |
| CPI excluding food and energy | $\pi^e=\pi_{t-1}$ | -0.104<br>(0.054) | 10.92<br>(2.89) | 21.29<br>(1.75) | 0.706 |
| CPI without taxes, excluding food and energy | $\pi^e=\pi_{t-1}$ | -0.102<br>(0.092) | 9.83<br>(4.86) | 21.86<br>(1.93) | 0.696 |
| GDP Deflator | $\pi^e=\pi_{t-1}$ | -0.033<br>(0.023) | 4.35<br>(6.52) | 23.76<br>(3.01) | 0.572 |

Notes: see previous table.

Table A.3.3. ESTIMATES OF THE TVP NAIRU MODEL FOR ALTERNATIVE PRICE DEFINITIONS

(Smoothness parameter $\sigma_\eta$=0.02)

| | (a) | (b) | (c) | (d) | (e) |
|---|---|---|---|---|---|
| Price definition | CPI | CPI | CPI excluding food and energy | CPI without taxes, food and energy | GDP deflator |
| Formation of $\pi^e$ | $\pi^e=\pi_{t-1}$ | $\pi^e$=ARIMA forecast | $\pi^e=\pi_{t-1}$ | $\pi^e=\pi_{t-1}$ | $\pi^e=\pi_{t-1}$ |
| B (1) | -0.126 | 0.158 | -0.121 | -0.111 | 0.109 |
| | (0.034) | (0.035) | (0.029) | (0.021) | (0.016) |
| Estimates of NAIRU | | | | | |
| 1982:1 | 15.27 | 13.53 | 14.89 | 16.28 | 13.54 |
| 1986:1 | 22.80 | 19.46 | 24.72 | 22.69 | 18.59 |
| 1991:2 | 19.67 | 16.63 | 19.72 | 19.67 | 16.07 |
| 1994:1 | 21.19 | 20.29 | 21.35 | 20.45 | 21.93 |
| 1999:3 | 19.21 | 21.24 | 18.52 | 20.51 | 22.80 |
| $R^2$ | 0.846 | 0.613 | 0.757 | 0.749 | 0.705 |

**APPENDIX 4. THEORETICAL CONSIDERATIONS FOR THE STRUCTURAL APPROACH**

## The price equation

The representative firm is characterised by a certain monopoly power in the product market and its target is to maximise profits. Taken as given are wages, demand, competitor prices (including import prices) and capital stock to decide the prices to charge, the employment to hire and the production. Let us assume that production is characterised by a Cobb-Douglas production function with constant returns to scale on employment (N) and capital (K):

$$Y = A(\Lambda N)^{a} K^{1-a} \qquad \text{[A.4.1]}$$

where Y is output and $\Lambda$ is labour-augmenting technical progress (thus, $\Lambda$N is labour in efficiency units). As we assume imperfect competition, prices are set as a mark-up over marginal cost. Then, the standard first-order conditions that input prices equal marginal costs are extended to allow for a positive mark-up (m).

$$\frac{P}{1+m} a \frac{Y}{N} = W \qquad \text{[A.4.2]}$$

$$\frac{P}{1+m} (1-a) \frac{Y}{K} = UC \qquad \text{[A.4.3]}$$

where W is the nominal wage and UC is the user cost of capital. Expression [A.4.1] may be rewritten as:

$$N = \frac{1}{\Lambda} \left( \frac{Y}{A} \right)^{\frac{1}{a}} K^{\frac{a-1}{a}} \qquad \text{[A.4.4]}$$

Substituting [A.4.4] into [A.4.2], assuming $\Lambda = e^{\beta tr}$ (meaning that technological progress is modeled as a trend) and taking logs (lower-case letters refers to logarithms) enable us to write the price equation as:

$$p = -\ln a - \frac{1}{a} a - btr + \ln(1+m) + \frac{1-a}{a}(y-k) + w \qquad \text{[A.4.5]}$$

Assuming that the mark-up depends on competitiveness, we specify the following equation for the mark-up:

$$\ln(1+m) = \gamma_0 + \gamma_1 (p^* - p) \qquad [A.4.6]$$

where P* denotes import prices in domestic currency. Expression [A.4.6] indicates that an increase in international competitiveness makes domestic demand less elastic. Thus, when external prices are high, domestic firms can raise their prices and expand their mark-ups. Substituting [A.4.6] into [A.4.5], yields the expression:

$$p = \Psi_p - \frac{\beta}{1+\gamma_1} t + \frac{\gamma_1}{1+\gamma_1} p^* + \frac{1-\alpha}{\alpha(1+\gamma_1)}(y-k) + \frac{1}{1+\gamma_1} w \qquad [A.4.7]$$

where $\Psi_p$ is a constant.

## The wage equation

Let us consider the following objective function for the trade union:

$$V = SW + (1-S)A \qquad [A.4.8]$$

where S is the probability of being employed next period and A is the expected income of a worker who loses his job. This may be defined as:

$$A = (1 - p(u,\varphi))W + p(u,\varphi)B \qquad [A.4.9]$$

where p(u,φ) is the probability of not finding an alternative job, u is the unemployment rate, φ other variables that increase the probability of finding a job at given levels of unemployment and B is the unemployment benefit.

The bargaining process will maximise:

$$\Omega = (V - A)^{\gamma}\Pi = \left[(W - A)S\right]^{\gamma}\Pi \qquad [A.4.10]$$

where γ measures union bargaining power and Π denotes firm operating profit (assuming that alternative profits are zero).

The first-order condition of the bargaining problem is given by:

$$\frac{\partial \ln \Omega}{\partial W} = \frac{\gamma}{W-A} + \frac{\gamma}{S}\frac{\partial S}{\partial W} - \frac{1}{\Pi}\frac{\partial \Pi}{\partial W} = 0 \qquad [A.4.11]$$

Rearranging [A.4.11] we find an expression for the wage mark-up over alternative income:

$$\frac{W-A}{W}=\frac{1}{e_{pw}-\frac{1}{g}e_{sw}}=0 \qquad \text{[A.4.12]}$$

where $\varepsilon_{\pi w}$ and $\varepsilon_{sw}$ are the elasticities of profits and the survival probability (probability of being employed next period) with respect to wages.

Using the production function and log-linearising the corresponding expression[29] we obtain our wage equation (expression [8] in the main text):

$$w=\Psi_w-\frac{1-a}{a}(y-k)+b\,tr+-c_1u+c_2 j\ +c_3 b+c_4\, g+\ p \qquad \text{[A.4.13]}$$

where $\Psi_w$ is a constant.

[29] See Layard et al. (1991) for a detailed derivation.

## APPENDIX 5. PRICE INFLATION SETTING IN A FORWARD-LOOKING FRAMEWORK

Let us assume that in the economy there is a continuum of firms. Each firm is a monopolistic competitor producing a differentiated good. Following the formalism introduced in Calvo (1983), we assume that each firm resets its price only with probability (1-q) each period, irrespective of the time elapsed since the last adjustment, so a fraction, q, keep their prices unchanged. In such an environment the law of motion for the aggregate price level (in logs) can be approximated by:

$$p_t = qp_{t-1} + (1-q)\,p_t^T \qquad \text{[A.5.1]}$$

where $p^T$ represents the log of newly set prices. Accordingly, the inflation rate is given by:

$$\Delta p_t = \left(\frac{1-q}{q}\right)(p_t^T - p_t) \qquad \text{[A.5.2]}$$

As shown, for instance, by Galí and Gertler (1999), the optimal price-setting rule for a firm facing an isoelastic demand for its product and subject to the constraint on price adjustment described above can be approximated by:

$$p_t^T = p_t + (1-bq)\sum_{j=0}^{\infty}(bq)^j E_t\left[(p_{t+j} - p_t) - m_{p_{t+j}}\right] \qquad \text{[A.5.3]}$$

where $\mu_{pt+j}$ denotes the deviations of a firm's mark-up from its steady state value. Thus, newly set prices are a function of (a) the current aggregate price level, (b) current and anticipated economy-wide real marginal costs, and (c) current and anticipated inflation, with the weights associated with each future horizon proportional to the probability that the chosen price remains effective at that horizon. Using the previous expressions it is possible to obtain the so-called New Phillips curve, as:

$$\Delta p_t = bE_t\Delta p_{t+1} - l_p m_{p_t} \qquad \text{[A.5.4]}$$

A stylised fact in market economies is the existence of sticky inflation (see Fuhrer and Moore [1995] for the US and Coenen and Wieland [1999] for Europe). In order to allow for that, we consider that the previous forward-looking price setup only affects a fraction of firms in the economy, while for the rest of the firms, we have a backward-looking behaviour setting current prices in terms of past prices. Under such circumstances, the Phillips curve takes the following form:

$$\Delta p_t = g_f^p E_t \Delta p_{t+1} + g_b^p \Delta p_{t-1} - l_p m_{p_t} \qquad [A.5.6]$$

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