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**How much has labour taxation contributed to European structural unemployment?**

by


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**ABSTRACT**

This paper analyses the effect of labour taxes on Euro area unemployment. Empirical estimates obtained so far can be criticised as being spurious because the regressions generally lack non-measurable variables constituting the reservation wage that can possibly be non stationary. Here we overcome this problem by using an unobserved component model. For the Euro area unemployment, we find a significant tax effect that is in the middle of the estimates that can be found in the empirical literature. This study gives support to the view that lowering labour taxes can help to reduce unemployment in continental Europe.

## 1. Introduction

There exists a long debate in the economics profession about the effect of labour taxation on unemployment. Though most theories of the labour market acknowledge the existence of a causal relationship, no general agreement about the actual tax elasticity of unemployment has yet been reached. Unemployment tax elasticity is here defined as the percentage point increase in the unemployment rate associated with a one-percentage point increase in the labour taxation rate. For the European Union, the empirical evidence ranges from the total absence of an effect (see Blanchard and Wolfers, 2000) to an unemployment tax elasticity of up to .5 (see Daveri and Tabellini, 2000). Such a large discrepancy is unfortunate because these different empirical results imply conflicting strategies for reducing unemployment. Obviously, according to Blanchard and Wolfers, labour tax reforms should be dismissed as a strategy to combat European unemployment. But according to Daveri and Tabellini, the rise in labour taxation could be responsible for more than 50% of the increase in unemployment in continental Europe since the beginning of the 1970's, and therefore a reduction in labour taxes would be strongly advisable. Since different empirical results lead to radically different strategies for reducing unemployment, there is a clear need to further extend the empirical evidence.

It is legitimate to ask why it is so difficult to reach a consensus about the actual effect of labour taxation on unemployment. In a recent survey, Daveri (2001) puts the emphasis on a missing variable problem. Empirical research on labour markets faces such a problem because economic theory relates the level of unemployment to two concepts that are indeed difficult to measure: the level of the reservation wage and the mark up of wages over the reservation wage. These two variables are not observable, partly because they relate to non-market activities involving prices or shadow prices that are not reported to statistical offices, and partly because they reflect the labour market structure. For instance, the reservation wage involves elements such as the value of leisure, the value of home production and the wage that can be earned in the shadow economy. The mark up of wages over the reservation wage depends, among other factors, on the bargaining strength of trade unions, on the structure of the bargaining process between workers and firms, on labour market regulations such as hiring and firing rules and, under certain conditions, on technical progress. The only variable influencing the wage mark up that is in principle observable is the labour tax rate. The missing variables are especially important in this context because they can be partly responsible for the non-stationary behaviour of unemployment series, and an improper treatment may lead to spurious regression results.

The presence of unobserved structural determinants of unemployment is well acknowledged in the literature and accordingly it has become customary to resort to unobserved components models when estimating structural unemployment rates. Apel and Jansson (1999a, 1999b) for instance estimate the NAIRU with all structural determinants taken as unobserved. In this article we estimate the effect of labour taxes on European unemployment by modelling structural unemployment as made up of two elements: a non-stationary unobservable component related to the non-measurable factors plus an observed component that represents the effect of labour taxes. Together they capture the non-stationary behaviour of unemployment. To our knowledge no attempt has been made to jointly estimate observed and unobserved structural determinants of unemployment. Our approach yields consistent estimates, in spite of missing variables, as long as taxes are orthogonal to the other unobservable structural factors. It also provides some information on the evolution of the unobserved structural shocks, an information that we believe can be helpful in the search for other relevant variables capable of explaining the European unemployment trend.

Starting from standard models of the labour market, we show in Section 2 how taxes determine the structural unemployment rate together with other factors. The econometric model implied by this framework and the econometric methodology implemented is discussed in Section 3. In Section 4, we present our empirical results obtained with EU-12 yearly data for the period 1970 to 2002. Section 5 concludes.

## 2. Labour taxes in standard labour market models

Following standard textbooks, there are broadly four different hypotheses trying to describe the labour market: the neoclassical view, the efficiency wage approach, the wage bargaining theory and the search model. Pissarides (1998) has examined how labour taxes can affect wage rules in these four frameworks; we follow his approach very closely. The notations are those of Blanchard and Katz (1999); this helps to clarify how our formulation slightly generalises the standard NAIRU model. All four hypotheses can be regarded as special cases of the following generic wage-setting rule

$$w_t - tax_t - p_t^e = (1-\mu)b_t + \mu(y_{t-j} - l_{t-j}) - \beta u_t + a_t^w \qquad (1)$$

Workers/trade unions negotiate a nominal wage $w_t$ net of labour taxes $tax_t$ at time t conditional on the price expectation $p_t^e$, on the level of the reservation wage $b_t$, on the possibly lagged labour productivity $y_{t-j} - l_{t-j}$ and on the unemployment rate $u_t$.

The term $a_t^w$ is a shock to the wage-setting rule that can be autocorrelated. As shown by Pissarides, the four macroeconomic theories imply certain restrictions on the parameter values of equation (1): both the neoclassical and the efficiency wage models imply $\mu = 0$, i.e. wages are not directly linked to productivity. The wage bargaining and the search model allow instead for productivity to play a role. The magnitude of productivity indexation therefore depends crucially on the bargaining strength of workers. In an atomistic labour market without any market power for workers such as in the neoclassical model, wages would be equal to the reservation wage. By contrast, in a highly unionised labour market, $\mu$ would approach unity.

Theories also differ in the specification of the reservation wage. In the neoclassical model the reservation wage would be the value of leisure, a concept derived from a utility function for workers which is defined in terms of consumption and leisure. Consequently, in the neoclassical model consumption and leisure time would be the arguments of $b_t$. While the value of leisure could also play a role under the other hypotheses, these generally stress a non-market wage as an alternative. The non-market wage could be for instance unemployment benefits, the value of home production or the income earned in the shadow economy. Without loss of generality, it will prove useful to express the reservation wage as a function of the market wage,

$$b_t = b_t^0 + (w_{t-i} - p_{t-i} - \kappa tax_{t-i}) \qquad (2)$$

where $b_t^0$ is the logarithm of the replacement rate. This formulation captures various possible hypotheses of the reservation wage. For our analysis, the response of the reservation wage to the tax rate is most important. This dependence is captured by the parameter $\kappa \in [0,1]$, which determines whether the reservation wage is more closely indexed to gross or net wages. Low values for $\kappa$ would be obtained for an economy with a large informal sector or alternatively with a social security system where unemployment benefits are indexed to gross wages. Since leisure is not taxed, the neoclassical model would also predict a low value for $\kappa$. Notice that as $b_t^0$ is allowed to vary over time, the formulation (2) is not restricting the dynamics of the reservation wage.

In order to determine the structural unemployment rate, labour demand must be introduced. Following standard practice we assume a labour demand schedule derived from a Cobb-Douglas production function:

$$ws_t = w_t - p_t - (y_t - l_t) \quad (3)$$

We allow the wage share $ws_t$ to fluctuate over time around its equilibrium value that we denote with ws*. These fluctuations could be due to cyclical movements in the mark-up or to partial adjustment of employment to changes in demand or real wages. Hence the wage share is given by

$$ws_t = ws^* + \varphi_t . \quad (4)$$

Because it may take some time for labour demand to adjust to new economic conditions, $\varphi_t$ can be an autocorrelated process that can itself depend on current and past values of employment, output and real wages. As will be seen below, for our analysis it is not necessary to explicitly specify the dynamics of the wage share. In order to complete the description of the model, the expectations formation must be characterised. Following standard practice in this literature we assume static-backward looking inflation expectations:

$$p_t^e - p_{t-1} = p_{t-1} - p_{t-2} . \quad (5)$$

Our specification of the labour market is similar to the model used by Blanchard and Katz (1999). The only difference is that we allow for an explicit role for labour taxation.

Equations (1) to (5) determine an equilibrium unemployment rate for a given level of taxes and of the replacement rate. The equilibrium is defined as an outcome without expectation errors, i.e. $p_t^e = p_t$, and where the wage share is equal to its equilibrium value, i.e. $ws_t = ws^*$. Under these conditions, the equilibrium unemployment rate is given by

$$u_t^* = [\{1 - (1-\mu)\kappa\}tax_t + (1-\mu)b_t^0 - \mu ws^*]/\beta \quad (6)$$

Equation (6) shows that the equilibrium level of unemployment depends positively on both the level of labour taxation and the replacement rate, and negatively on the equilibrium wage share. Notice also that, theoretically, the impact of labour taxes on the level of unemployment depends on three factors: the bargaining strength, the indexation of the reservation wage to labour taxes, and the elasticity of wages with respect to the unemployment rate.

From (1) to (6) we can derive a dynamic equation for the evolution of nominal wages that is the so-called Phillips curve implied by this model. The general specification is given by (see Appendix):

$$\Delta^2 w_t = c + \sum_{m=0}^{1} \alpha_m \Delta(y_{t-m} - l_{t-m}) + \sum_{n=0}^{2} \theta_n ws_{t-n} + \xi \Delta tax_t - \beta(u_t - u_t^*) + a_t^w \qquad (7)$$

The dynamics of wages will in general depend on the lag structure of the wage equation (1) and of the reservation wage equation (2). Table 1 below displays the parameter values for different lags.

**Table 1: Parameter values in (7) and lag structure in (1)-(2)**

| | $\alpha_0$ | $\alpha_1$ | $\theta_0$ | $\theta_1$ | $\theta_2$ | $\xi$ |
|---|---|---|---|---|---|---|
| i=0, j=0 | 1 | -1 | 1-$\mu$ | -2 | 1 | 0 |
| i=1, j=1 | 0 | -1 | 0 | -1-$\mu$ | 1 | (1-$\mu$)$\kappa$ |
| i=0, j=1 | 1-$\mu$ | -1 | 1-$\mu$ | -2 | 1 | 0 |
| i=1, j=0 | $\mu$ | -1 | 0 | -1-$\mu$ | 1 | (1-$\mu$)$\kappa$ |

Table 1 shows that the coefficients of both the wage share and labour productivity in the Phillips curve depend on the lag structure. The sign of the response of wages to productivity depends strongly on the timing of the response: in particular, there is a sign switch between contemporaneous and one-period later adjustment. The change in labour taxes has an effect only when the reservation wage reacts to the market wage with a one-period delay. As expected, a positive departure from unemployment equilibrium always yields negative pressure on wage inflation. The values in the table are meant to give some guidance in interpreting our empirical results, but we do not expect that one set of restrictions holds identically since this derivation is based on fairly simple assumptions on expectations formation. Also the duration of wage contracts will not necessarily strictly coincide with the calendar year as assumed here.

## 3. The econometric model specification

Let us denote $u_t^C$ as the short-term fluctuations around the equilibrium unemployment rate $u_t^*$. Actual unemployment can be written as

$$u_t = u_t^* + u_t^C . \quad (8)$$

Equation (6) implies that the equilibrium unemployment rate is made up of a labour taxes effect and of an unobserved variable $u_t^N$ like in:

$$u_t^* = \gamma\, tax_t + u_t^N \quad (9)$$

where from (6) $\gamma = [1-(1-\mu)\kappa]/\beta$ and $u_t^N = [(1-\mu)b_t^0 - \mu ws^*]/\beta$. Since, besides the fact that it must catch long term movements, no further information on $u_t^N$ is available, a flexible enough stochastic process is preferable. We consider a second order random walk (see Harvey, 1989, chapter 2) that is specified according to:

$$(1-L)u_t^N = \lambda_{t-1} + a_t^N \quad (10)$$

where L is the lag operator and the slope $\lambda_t$ is itself a random walk such that:

$$(1-L)\lambda_t = a_t^\lambda \quad (11)$$

The random variables $a_t^N$ and $a_t^\lambda$ are orthogonal Gaussian white noises with variances $V_N$ and $V_\lambda$ respectively. Notice that $V_\lambda = 0$ yields a random walk plus drift process while $V_N = 0$ implies an I(2) model. The short-term movements are described as a stationary autoregressive process of order 2:

$$(1-\phi_1 L - \phi_2 L^2)u_t^C = a_t^C \quad (12)$$

where $a_t^C$ is a Gaussian white noise with variance $V_C$ orthogonal to $a_t^N$ and $a_t^\lambda$.

Unlike in previous exercises that treat the structural component of unemployment as unobserved, our specification (8)-(12) explicitly distinguishes between observed and unobserved elements. This specification is completed with the Phillips curve equation (7) that links the acceleration of wage inflation to the unemployment gap. The variable $a_t^W$ is assumed to be a Gaussian white noise with variance $V_W$ orthogonal to the innovations in (10)-(12).

Model (7)-(12) is a bivariate unobserved component model with 15 parameters, namely $V_N$, $V_\lambda$, $V_C$, $V_W$, $\phi_1$, $\phi_2$, $\gamma$, $c_w$, $\alpha_0$, $\alpha_1$, $\theta_0$, $\theta_1$, $\theta_2$, $\xi$, and $\beta$. This might appear to be a large number of parameters, but one should keep in mind that a fair amount of exogenous information is supplied by the labour taxation, wage share and labour productivity variables. We estimated the model parameters by maximum likelihood after casting equations (7)-(12) in a state space format (see Harvey, 1989). As this model contains a non-stationary unobserved component, we used de Jong's (1991) diffuse Kalman filter for initialising the state vector and its covariance matrix. We run the collapsed version of de Jong's algorithm (see also Durbin and Koopmans, 2001, pp.115-118). Standard deviations of model parameters were obtained by inverting the minus Hessian matrix evaluated at the maximum likelihood parameter estimates. The unobserved component estimates are produced after smoothing with the fixed-point smoother algorithm (see Harvey, 1989, pp.151-154)[1].

## 4. Empirical results

We evaluate tax effects on European unemployment within the framework of model (1)-(7) using Euro area annual data for the period 1970 to 2002. Unemployment rate, wage income and labour productivity data are taken from DG ECFIN's national accounts databank, AMECO. Following the classification in Daveri and Tabellini (2000), the EU 12 aggregate consists mostly of "continental European countries" for which these authors find the highest tax effects. It excludes the "Scandinavian countries", with the exception of Finland, and the "Anglo Saxon countries" for which they report only small tax effects. Both the periodicity and the starting point of our data set are dictated by the availability of effective tax rates. These are constructed by the European Commission (DG ECFIN) using the Mendoza, Razin and Tesar (1994) methodology. A full description of the procedure can be found in Martinez-Mongay (2000). In brief, the effective tax rate is defined as the ratio of labour tax revenue to the taxable base. Labour tax revenue consists of labour taxes plus social security contributions as annually reported by OECD government statistics (OECD, 2000).

Figure 1 shows the EU 12 unemployment rate and effective labour tax rate over the period 1970-2002. It can be seen that the long-term movements of the two variables are globally upwardly sloped over the last 30 years. Both unemployment and labour

[1] A Fortran program together with an Excel interface has been built for performing these tasks. It can be freely downloaded at http://www/jrc/cec/eu/int/uasa/project-ts.asp, following the link Program Gap-Further Information.

tax rate reach their maximum values during the period 1994-1997 and then they start to decline.

We first estimate model (7)-(12) without labour taxes. Table 2 displays the results. Standard diagnostics such as the Ljung-Box statistics (see Ljung and Box, 1981) computed on the first four residual autocorrelations are also reported. No particular specification problem appears. Altough not displayed in Table 2, the Bowman-Shenton normality test (see Harvey 1989, p.260) suggests that the properties of the residuals of the two measurement equations are not significantly different from those of a normal distribution. According to t-tests, the hypothesis that $\theta_2 = 1$ cannot be rejected at the 5% level. The parameter $\alpha_1$ is instead found significantly different from -1 but it has nevertheless the sign that we anticipated. The parameter $\beta$ also takes the positive sign we expected and with a t-value of 2.0. The negative pressures that short-term increases in unemployment put on wage inflation are found significant at the 5% level. The parameters $\phi_1$ and $\phi_2$ imply that these short-term movements in unemployment would have a periodicity of about 10 years, somewhat in agreement with typical business cycle lengths. The innovation variance $V_N$ is estimated as 0, so the second-order random walk (10)-(11) reduces to an I(2) model for capturing the long-term movements in unemployment. Finally the relatively high $R^2$ of .5 on the Phillips curve, suggests that our bivariate model describes fairly well the change in wage inflation.

**Table 2: Estimation results (1970-2002)***

**Unemployment equation**

$$u_t = u_t^* + u_t^C \qquad u_t^* = \gamma\, tax_t + u_t^N$$

$$(1-\phi_1 L - \phi_2 L^2) u_t^C = a_t^C \qquad (1-L)^2 u_t^N = a_t^\lambda$$

| | No labour taxes | With labour taxes | Restricted model |
|---|---|---|---|
| $\phi_1$ | 1.39 (.13) | 1.34 (.15) | 1.37 (.15) |
| $\phi_2$ | -.70 (.13) | -.63 (.14) | -.63 (.15) |
| $V_C$ | $1.54\times10^{-1}$ | $1.47\times10^{-1}$ | $1.54\times10^{-1}$ |
| $V_\lambda$ | $6.88\times10^{-3}$ | $2.78\times10^{-3}$ | $1.21\times10^{-3}$ |
| $\gamma$ | – | .32 (.15) | .32 (.14) |
| Q(4) | 2.90 [.58] | 2.64 [.62] | 2.75 [.60] |

**Phillips curve**

$$\Delta^2 w_t = c_w + \alpha_0 \Delta(y_t - l_t) + \alpha_1 \Delta(y_{t-1} - l_{t-1}) + \theta_0 ws_t + \theta_1 ws_{t-1} + \theta_2 ws_{t-2} + \xi \Delta tax_t - \beta(u_t - u_t^*) + a_t^w$$

| | No labour taxes | With labour taxes | Restricted model |
|---|---|---|---|
| $c_w$ | -.06 (.03) | -.04 (.04) | -.04 (.03) |
| $\alpha_0$ | .84 (.22) | .93 (.24) | .91 (.16) |
| $\alpha_1$ | -.39 (.24) | -.42 (.24) | -.52 (.17) |
| $\theta_0$ | .87 (.28) | 1.01 (.30) | .94 (.05) |
| $\theta_1$ | -1.73 (.46) | -1.85 (.46) | -2.0** |
| $\theta_2$ | .78 (.22) | .79 (.22) | 1.0** |
| $\beta$ | .45 (.22) | .46 (.24) | .54 (.19) |
| $\xi$ | – | $-.42\times10^{-2}$ ($.43\times10^{-2}$) | .0** |
| $V_w$ | $7.20\times10^{-5}$ | $7.4\times10^{-5}$ | $7.5\times10^{-5}$ |
| $R^2$ | .50 | .50 | .47 |
| Q(4) | 3.90 [.42] | 4.21 [.38] | 5.25 [.26] |
| -2×Log-likelihood | -220.39 | -224.38 | -222.50 |

Notes: (*) standard errors are displayed between parentheses and p-values in brackets.Q(4) represents the Ljung-Box statistics computed on the first four autocorrelations. (**) the parameter value is imposed.

Next we introduce labour taxes as an observed component of structural unemployment and re-estimate model (7)-(12). We must draw attention to an identification problem regarding the level of the contribution of labour taxes and of the unobserved factors. Trivially, as can be seen from (9), we can remove a constant from one variable and add it to the other one without modifying their sum. Such a problem can be overcome by focusing on the effect of the change in the variable. This is why we choose to concentrate on the effect of the increase in labour taxes since the year 1970. Table 2 reports the estimation results. It can be seen that the parameters are remarkably stable. This is a result that gives us some confidence about the models reliability. The only parameter that changes is $V_\lambda$: the insertion of labour taxes as an observed determinant of structural unemployment has lowered the signal to noise ratio from about 1/20 to 1/50. Labour taxes have thus captured part of the long-term movements in unemployment.

As can be seen from the regression results, the estimated coefficients are close to what we would expect from Table 1. In particular, the sign restrictions on the productivity term correspond to Table 1's third line where i=0 and j=1. Thus the regression results suggest that wages respond with a lag of one year to productivity but there is a contemporaneous response of the reservation wage to changes in the market wage. Also, the change in labour taxation has no significant effect on wages. The implied value of the parameter $\mu$ is about .1. Sometimes this parameter is interpreted as a measure of the bargaining strength of workers. According to t-tests, the hypothesis that the coefficients of the lagged wage share and of the change in labour taxes are $\theta_1=-2$, $\theta_2=1$, and $\xi=0$, as predicted by equation (7) when i=0 and j=1, cannot be rejected. Hence, in a third step, we set these three coefficients and we reestimate (7)-(12). This last formulation is labelled "Restricted model" in Table 2. Our model remains stable and the Phillips curve parameters are more accurately estimated. Figure 2 shows the actual unemployment series together with the structural series computed with and without labour taxes. It can be seen that the two NAIRUs are close, i. e. treating labour taxes as an observed determinant of structural unemployment or treating all determinants as unobservable yields similar enough results. This, we believe, confirms our expectation that labour taxes have an effect on the NAIRU itself.

Over the period 1970-2002 we find that the labour taxation variable has had an effect on EU-12 unemployment. This effect is significant at the 5% level according to both the t-statistics and the likelihood ratio test. With a value estimated at .32, a decrease by 3 percentage-points in labour taxation would lead to roughly a 1 percentage-point decrease in the unemployment rate. This value corresponds to the lower bound of the range of estimates reported by Daveri and Tabellini (2000).

What is the price paid for the increase in labour taxes over the period 1970-2002? Figure 3 shows the contribution of the unobservable factors and of the increase in labour taxes since 1970 to the change in structural unemployment. It can be seen that each account for roughly half of the rise in structural unemployment. This confirms the results of Daveri and Tabellini (2000) who attribute 4 percentage points of the rise in EU unemployment to the rise in labour taxes.

Finally, Figure 4 shows the unemployment gap as computed from the last model labelled "Restricted", together with 10% confidence bands around a 0-gap. It can be seen that the first half of both the 1980's and the 1990's are periods of large positive departures from the unemployment equilibrium, while the decrease in the last years reflects the impact of the economic expansion phase.

## 5. Conclusion

In this paper we model structural unemployment as made up of two elements: one unobservable component related to the reservation wage and to the wage mark-up and an observed component, namely labour taxes. Our economic model implies a Phillips curve equation that we use in our econometric application. We then tested for the effect of taxes on structural unemployment, while giving a proper treatment to the problem of unemployment non-stationarity. In our framework, we found that labour taxes have had a significant impact on the Euro area NAIRU, and that the rise in labour taxes since 1970 has accounted for almost half of the rise in long-term unemployment. We estimated the tax elasticity of unemployment at .32, a value that lies in the middle of the estimates that can be found in the empirical literature. Our study confirms the Daveri and Tabellini (2000) conclusion about the importance of lowering labour taxes for fighting unemployment in continental Europe, although our tax elasticity estimates lie at the lower bound of the range of estimates they report. The adjustment parameters suggest a contemporaneous adjustment of the reservation wage and a delay of the wage response to changes in labour productivity of one year.

When estimating the unemployment tax elasticity, the non-stationarity of the unemployment series requires particular attention. If a cointegration relationship between unemployment, labour taxes and possibly other variables does not hold, then the results are likely to be spurious. If instead it does, then the NAIRU would actually be observed since the cointegration relationship catches the long-term movements, and this would be somewhat at odds with NAIRU theory. The approach we developed in this paper has the advantage of a proper treatment of the non-stationary behaviour of the unemployment series while allowing the NAIRU to be only partially unobserved.

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**Appendix: Derivation of the Phillips curve - equation (7)**

**Step1:** subtract $(w_{t-1} - p_{t-1})$ from both sides of (1) and define expected inflation as $\pi_t^e = p_t^e - p_{t-1}$:

$$\Delta w_t - \pi_t^e = (1-\mu)b_t - (w_{t-1} - p_{t-1}) + \mu(y_{t-j} - l_{t-j}) - \beta u_t + tax_t + a_t^w$$

**Step 2:** Substitute (2) into (1)

$$\Delta w_t - \pi_t^e = (1-\mu)b_t^0 + (1-\mu)(w_{t-i} - p_{t-i}) - (w_{t-1} - p_{t-1}) + \mu(y_{t-j} - l_{t-j}) - \beta u_t$$
$$+ tax_t - (1-\mu)\kappa\, tax_t + (1-\mu)\kappa\,\delta tax_t + a_t^w$$

where

$$\delta tax_t = \begin{cases} 0 & \text{if } i = 0 \\ \Delta tax_t & \text{if } i = 1 \end{cases}$$

**Step 3:** From equation (3), $w_t - p_t = ws_t + (y_t - l_t)$, hence:

$$\Delta w_t - \pi_t^e = (1-\mu)b_t^0 + (1-\mu)(ws_{t-i} + y_{t-i} - l_{t-i}) - (ws_{t-1} + y_{t-1} - l_{t-1}) + \mu(y_{t-j} - l_{t-j})$$
$$- \beta u_t + tax_t - (1-\mu)\kappa\, tax_t + (1-\mu)\kappa\,\delta tax_t + a_t^w$$

**Step 4:** Assume $\pi_t^e = \pi_{t-1}$. Then equation (3) implies:

$$\pi_t^e = \Delta w_{t-1} - \Delta(y_{t-1} - l_{t-1}) - \Delta ws_{t-1}$$

Substitute this expression into the result of Step 3.

$$\Delta^2 w_t = (1-\mu)b_t^0 + (1-\mu)(y_{t-i} - l_{t-i}) + \mu(y_{t-j} - l_{t-j}) - (y_{t-1} - l_{t-1}) - \Delta(y_{t-1} - l_{t-1}) +$$
$$+ (1-\mu)ws_{t-i} - 2ws_{t-1} + ws_{t-2}$$
$$- \beta u_t + tax_t - (1-\mu)\kappa\, tax_t + (1-\mu)\kappa\,\delta tax_t + a_t^w$$

**Step 5:** (6) implies $(1-\mu)b_t^0 + [1-(1-\mu)\kappa]tax_t = \beta u_t^* + \mu ws^*$. Plugging this last result into Step 4 yields:

$$\Delta^2 w_t = \mu ws^* + (1-\mu)(y_{t-i} - l_{t-i}) + \mu(y_{t-j} - l_{t-j}) - (y_{t-1} - l_{t-1}) - \Delta(y_{t-1} - l_{t-1}) +$$
$$+ (1-\mu)ws_{t-i} - 2ws_{t-1} + ws_{t-2} + (1-\mu)\kappa\,\delta tax_t$$
$$- \beta(u_t - u_t^*) + a_t^w$$

The coefficient values in (7) are then straightforward to recover.

**Figure 1**

EU 12 Unemployment (%) and Labour taxes (%) (1970-2002)

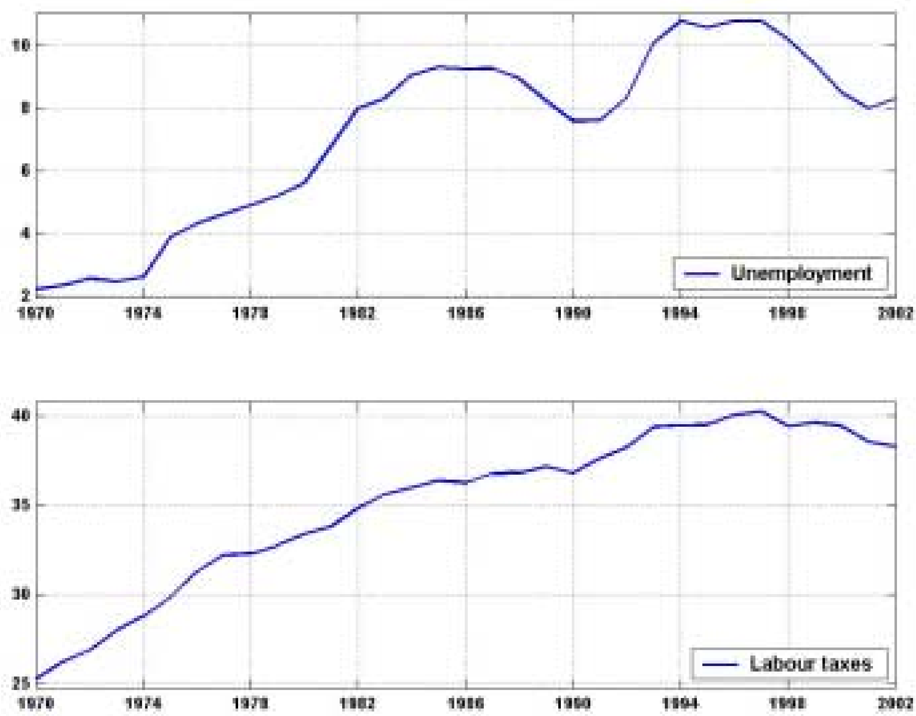

**Figure 2**

EU 12 Structural unemployment estimates

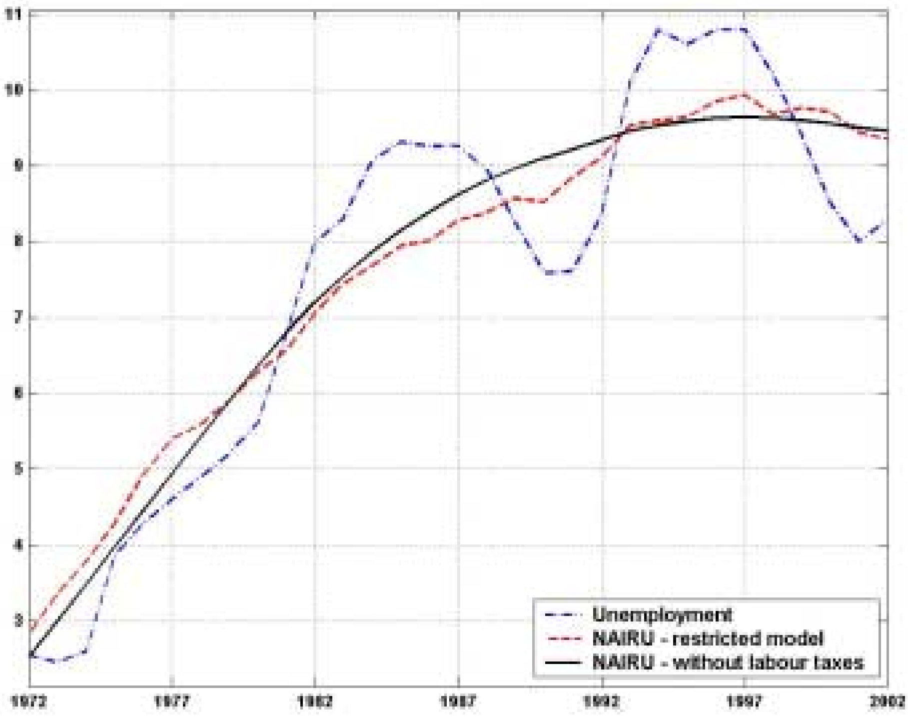

**Figure 3**

Observed and unobserved determinants of EU 12 structural unemployment

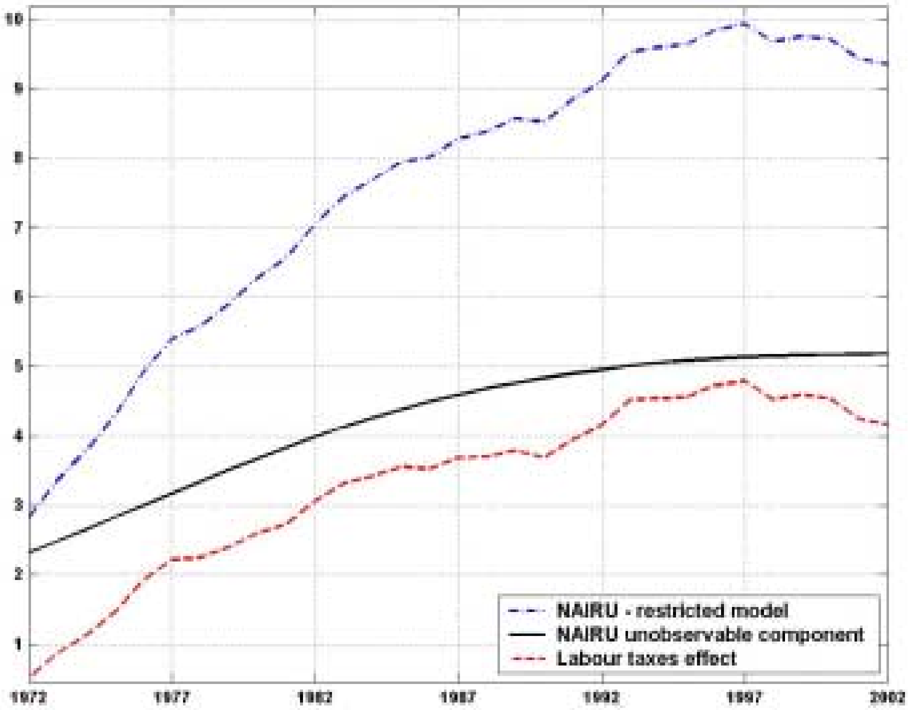

**Figure 4**

EU 12 Unemployment gap estimate – Restricted model