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TIME-VARYING NAIRU AND REAL INTEREST RATES IN THE EURO AREA

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ABSTRACT

This paper analyses the Nairu in the euro area and the influence that monetary policy had on its development. Using the Kalman-filter technique we find that the Nairu has varied considerably since the early 1970s. The Kalman-filter technique is applied here for the first time using explicit exogenous variables. In particular, real interest rates were found to explain a quarter of the increase in the Nairu between 1980 and 1995. This indicates the possibility of a long-run nonsuperneutrality of monetary policy.

JEL Classification: C32, E32, E52.

Keywords: Nairu, Monetary Policy, Kalman Filter, Phillips curve, Superneutrality.

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1. Introduction

The significant increase in the unemployment rate in Europe since the early 1970s did not occur gradually but in three big steps. In the United States similar upward jumps in the unemployment rate can be observed, in contrast to Europe, however, subsequent years always saw a decline in unemployment. Whereas shocks are widely held to be responsible for the large increases in unemployment in both regions, the question still remains as to what caused unemployment to remain relatively high in the euro area.

By using a state-space model to estimate the Nairu in the euro area since 1975 and to gauge the effect of certain exogenous variables we hope to contribute to this debate. There is ample evidence that institutional changes in the early 1970s contributed to the increase in the Nairu and thereby also pushed up actual unemployment. There seem to be limits, however, to what these factors can explain.[1] We therefore tested the effect of three other exogenous variables that find mention in the literature: tax wedge, productivity slowdown and real short-term interest rates.

The novel approach of applying the Kalman-filter technique with explicit exogenous variables allows us to quantify the effect of changes in these variables on the Nairu. We find that real interest rates have a significant effect, whereas the effect of changes in productivity turn out to be negligible and the effect of the wage wedge insignificant.

We interpret the rise in the short-term real interest rate as being the result of restrictive monetary policy. This combined with the significant effect of the real interest rate on the Nairu and hysteresis leads us to assert the role of monetary policy in the rise of the Nairu since the 1980s. In addition we test for the long-term super-neutrality of money and find it rejected. Therefore our hypothesis is that a restrictive monetary policy stance maintained over a longer period of time gives rise to hysteresis in the labour market and thereby affects the level of real economic activity beyond the short term.

The remainder of the paper is structured as follows: In the next section we sketch the way in which we apply the Kalman-filter technique and discuss the properties of the data used. Section 3 presents the outcome of the Kalman-filter regression of the euro-area Nairu using explicit exogenous variables. In section 4 we place these results into the larger macroeconomic context and discuss the mechanisms and implications of a long-run nonsuperneutrality of money. Section 5 concludes the paper.

[1] Cf. Nickell et al. (2002, pp. 394-440), Machin & Manning (1999, p. 3107) and Blanchard & Katz (1997, p. 68).

2. Modelling the Nairu and the Phillips curve for the euro area

The Kalman-Filter technique (state-space modelling) offers a fruitful approach to estimating the Nairu because it is designed to identify an unobservable variable – like the Nairu – on the basis of assumptions made about the econometric properties of the variable and the economic interrelation between this variable and other observable variables.[2] In what follows we model the Nairu as an instationary trend and estimate it simultaneously with a Phillips curve, the latter being the relationship through which the unemployment gap – the deviation of actual unemployment from the Nairu – affects inflation. We use a procedure presented by Kuttner (1994, pp. 361-368).

The unemployment gap is modelled as an AR(2) process and the instationarity of the Nairu as a local linear model (see Appendix A1). The Phillips curve is derived from two equations: a wage-setting equation (1) and a price-setting equation (2) (Layard, Jackman and Nickell, 1991, pp. 361-396).

Wages (w) are dependent on adaptive price expectations ($p^{cpi,e}$), labour productivity (prod) and on the general conditions in the labour market that are here proxied by the unemployment gap (u-u*).

(1) $$\Delta w_t = \alpha_1 \Delta p_t^{cpi,e} + \alpha_2 \Delta prod_t - \beta_0^{'}(u - u^*)_t + \varepsilon_t$$ Wage setting (WS)

The wage share follows from the WS-equation and can vary over time (the coefficients α_1 and α_2 are not set equal to 1). Lower case letters stand for logarithms and Δ for the first difference.

Prices are determined by marginal costs, a mark up and supply shocks, the latter being proxied by the oil price (p^{oil}).[3] The coefficients β_1 and β_2 are not restrained.

(2) $$\Delta p_t^{cpi} = \beta_1 \Delta w_t - \beta_2 \Delta prod_t + \Delta markup_t + \delta \Delta p_t^{oil} + \nu_t$$ Price setting (PS)

The Phillips curve is obtained by putting the wage equation into the price equation.

$$\Delta p^{cpi} = \pi_t = \alpha_1 \beta_1 \pi_t^e + (\beta_1 \alpha_2 - \beta_2)\Delta prod_t - \alpha_1 \beta_0^{'}(u - u^*)_t + \Delta markup_t + \delta \Delta p_t^{oil} + \varepsilon'_t$$

Expectations are modelled as a backward-looking process:

$$\pi_t^e = \gamma \pi_{t-1}$$

[2] Kalman-filter estimates of the Nairu of the OECD are found in Turner *et al*. (2001, pp. 171-216); for the IMF see Laxton *et al*. (1998) and International Monetary Fund (2001) as well as De Masi (1997, pp. 40-46) for the different methods used by the IMF to estimate the Nairu and potential output. Denis, McMorrow and Röger (2002) provide the Kalman-filter estimate of the EU Commission.

[3] By including the price of oil in the Phillips curve we eliminated the effect of the oil price on inflation. Turner *et al.* (2001, pp. 171-216) and the International Monetary Fund (2001) do pretty much the same, however they put the real oil price as well as additional supply shocks, such as real import prices, into the Phillips curve. Otherwise an increase in inflation due to an oil price shock would be attributed to the unemployment gap and would imply an increase in the Nairu, given unchanged unemployment. It follows that in the Kalman-filter regression the effect of oil price changes on inflation is also eliminated. We do not however thereby eliminate the effects of oil price changes on the Nairu but only those on inflation: If the change in relative prices resulting from an oil price shock cause the Nairu to increase – either because real wages do not adjust accordingly or productive capacities are reduced – this increase will show up in our estimate. The rationale for eliminating the direct effect of the oil price is that a price level jump due to an adverse supply shock cannot be prevented by a central bank, not even if it acted very restrictively. In the economic profession it has furthermore become common sense that central banks should not react to supply shocks cf. Ball and Mankiw (1995, pp. 161-193), Shapiro (1994, pp. 611-615) and Taylor (1996, pp. 181-195).

The choice of adaptive expectations can be justified on the grounds that employees try to compensate for past losses in purchasing power and that the model yields good results under this assumption ($\gamma \in [0,1]$).[4]

The Phillips curve is:

(3)
$$\pi_t = \gamma' \pi_{t-1} + (\beta_1 \alpha_2 - \beta_2) \Delta prod_t + \beta_0 (u - u^*)_t + \Delta markup_t + \delta \Delta p_t^{oil} + \varepsilon'_t$$
$$\text{with } \gamma' = \alpha_1 \beta_1 \gamma \quad \text{and} \quad \beta_0 = -\alpha_1 \beta_0'$$

We do not assume the mark up to be constant, but rather follow Hall (1986, pp. 285-322) who emphasises the cyclical behaviour of the mark up and successfully tested for it empirically.[5] Since the unemployment gap captures this pro-cyclicity one of the two variables is redundant in the equation. We therefore omitted the mark up.

The Phillips curve thus becomes:

(4)
$$\pi_t = \gamma' \pi_{t-1} + (\beta_1 \alpha_2 - \beta_2) \Delta prod_t + \beta_0 (u - u^*)_t + \delta \Delta p_t^{oil} + \varepsilon'_t$$
$$\text{with } \gamma' = \alpha_1 \beta_1 \gamma \quad \text{and} \quad \beta_0 = -\alpha_1 \beta_0'$$

One of the reasons for the increasing popularity of the Kalman filter is the fact that it makes it possible to estimate an unobserved variable with relatively limited data. The key idea is to divide the unemployment rate into two components: the unemployment gap and the Nairu. Both components are unobservable. But by assumption, the unemployment gap significantly influences inflation. The Nairu indicates how much an economy can and must grow in order to prevent both inflationary and deflationary tendencies. The Kalman filter uses this economic relationship embodied in the Phillips curve as well as the assumed statistical properties of both components (their stochastic) to extract both unobservable variables from the data.

The state-space model is written below. The first three equations specify the stochastic properties of the unobserved variables (state equations). The fourth equation is a definition, defining the unemployment rate as the sum of the unemployment gap and Nairu. The last equation (observation equation) is the Phillips curve that describes the interrelation between the unobserved unemployment gap and the observed inflation rate. The coefficient β_0 should be negative.

(5)
$$\begin{aligned}
(u - u^*)_t &= ar_1 (u - u^*)_{t-1} + ar_2 (u - u^*)_{t-2} + \varepsilon_t^{ugap} \\
NAIRU_t &= NAIRU_{t-1} + trend_t + \delta d(Z^{nairu}{}_t) + \varepsilon_t^{nairu} \\
trend_t &= trend_{t-1} + \varepsilon_t^{trend} \\
u_t &= (u - u^*)_t + NAIRU_t \\
\pi_t &= \beta_0 (u - u^*)_t + \gamma X^{phillips}{}_t + \varepsilon_t^{\pi}
\end{aligned}$$

In addition to quantifying the Nairu, it is possible to use the state-space model to identify those factors that determine it. So far, however, no one has made use of this possibility to analyse the Nairu. The factors of influence explicitly dealt with are measured by $\delta d(Z^{nairu}{}_t)$.

[4] Cf. Mankiw (2001, pp. C58f.); the sum of the coefficients of lagged inflation are not set equal to zero – for a discussion of this assumption see Sargent (1971, pp. 721-725) and Hall (1999, pp. 431-435).

[5] Martins and Scarpetta (2002) empirically find the mark up to move in an anti-cyclical manner for the G-5 countries (1970-1992). For our analysis it is irrelevant whether the movement is anticyclical or procyclical provided that it is correlated with the cycle.

$X^{phillips}_t$ contains exogenous variables that explain the development of inflation rate (lags of inflation, labour productivity and the oil price).

The Nairu is estimated for the aggregate euro area rather than for the individual countries. The latter has the disadvantage that the interdependence between economic developments in the individual countries is not taken into account unless one has multi-country models. The indirect method, however, has the advantage that existing differences in institutions and transmission mechanisms of shocks can be taken into consideration. Most of the data used is provided by Eurostat. For the period before 1991 the time series were combined with the corresponding time series in the databank of the ECB's Area Wide Model (AWM).[6] With the exception of interest rates, which were simply combined, the levels of the Eurostat series were extended back to 1970 by using the growth rates of the AWM series. The indexes are based on the year 1995. The data is seasonally adjusted and refers to the euro area with 11 member states, i.e. Germany, France, Italy, Spain, Netherlands, Austria, Portugal, Finland, Ireland, Belgium and Luxembourg. The time series for the price of oil (Brent, US-Dollar) is taken from the IMF's International Financial Statistics; the synthetic euro was constructed using the exchange rate series for the 11 member states provided by the US Federal Reserve; the weights correspond to each country's share in the euro area's real GDP in 1995. Table 1 and Chart 1 in Appendix A2 provide a synopsis of the data.

Table 1. Description of the data

Abbreviation	Name	Integration order*
cpi	log of HICP (1995=100)	I(2)
alq	unemployment rate (standardised)	I(1)
bipreal	log of real GDP (euro, 1995)	I(1)
lpr	log of labour productivity (real GDP/employee)	I(1)
poil_euro	log of the oil price index in euro (1995=100)	I(1)

Note: *The test results are presented in the annex.

3. Kalman-filter estimate of the Nairu using explicit exogenous variables

The first step in estimating the Nairu is an OLS-regression of the Phillips curve with an unemployment gap obtained with an HP-filter (λ=1600)[7] (see Appendix A3). This OLS-estimate serves as the benchmark for the subsequent steps of the Kalman-filter technique.

The Kalman-filter estimate is produced with the programme GAP (2.2) developed by the European Commission.[8] The results are reported in Table 2. The first part of the output table refers to the three state equations (the first three equations of the system 5), the second part to the Phillips curve.

[6] Eurostat, New Cronos Datenbank, Fagan, Henry and Mestre (2001); the data constructed by Fagan, Henry and Mestre (2001) can be found under http://www.ecb.int. For aggregation real GDP weights were used, the German data was adjusted to fit the level of unified German data.

[7] The Hodrik-Prescott filter does nothing more than to smooth a given series; economic relationships such as the effect of the unemployment gap on inflation do not come into consideration.

[8] The programme is available free of charge under http://webfarm.jrc.cec.eu.int/; questions concerning the programme can be addressed to the authors of this paper or to christophe.planas@jrc.it and alessandro.rossi@jrc.it (The European Commission, Joint Research Centre, Italy).

Table 2. Output of the Kalman-filter estimate with exogenous variables

PROGRAM GAP version 2.2 (March 2002)			
Model type: Bivariate (unemployment gap as AR(2) and Nairu as local linear model)			
Z^{nairu}: lagged growth rate of productivity, lagged real interest rate (3 coefficients to estimate)			
$X^{phillips}$: lagged inflation rate, oil price inflation rate, unemployment gap (7 coefficients to estimate)			
Likelihood maximised by a Newton like algorithm; Standard errors computed using Information matrix			
Nb of obs.: 108			
Maximum likelihood estimates and stats			
Variables	Coefficients	S.E.	t-stat
State equations			
AR1	1.9472		
AR2	-0.9700	lower bound reached	
Trend innov var	4.12E-07		
Trend slope var	3.67E-07		
Cycle innov var	4.51E-08		
dlog(Prod, -1,-4,-6)	-0.0185	0.0053	-3.5134
Real int. rate(-6)	0.0358	0.0141	2.5471
Real int. rate(-3->-15)	0.0202	0.0104	1.9374
Total effect Prod.=-0.0555 → -0.06%-Point			
Total effect real int. rate=0.2984 → 0.3%-Point			
Phillips curve (observation equation)			
Intercept	--		
Unemployment gap	-0.1836	0.0672	-2.7336
D(CPI(-1))	0.3077	0.0778	3.9558
D(CPI(-3))	0.1671	0.0710	2.3546
D(CPI(-4))	0.3214	0.0856	3.7547
D(CPI(-5))	-0.1798	0.0786	-2.2868
D(CPI(-8))	0.3079	0.0633	4.8637
D(POIL_EURO)	0.0075	0.0018	4.0680
D(POIL_EURO(-3))	0.0063	0.0019	3.2879
Innovation var	6.79E-06		
-2*log-likelihood:	-2301.9056		

Residuals diagnostics	
First equation (state)	
Residuals autocorrelations	
r(1) = 0.0396	r(3) = 0.0160
r(2) = -0.1455	r(4) = 0.2254
Approximated standard deviation: 0.0962; Ljung-Box stat. Q(4) = 8.3764 p-value = 0.0787	
JB-Prob = 0.05	
Second equation (Phillips curve)	
Residuals autocorrelations	
r(1) = -0.0025	r(3) = -0.0148
r(2) = -0.0108	r(4) = 0.0847
Approximated standard deviation: 0.0962; Ljung-Box stat. Q(4) = 0.8582 p-value = 0.9305	
JB-Prob = 0.07 after elimination of an extreme value in 1980q1	
R-squared (uncentered) = 0.965	

We explicitly tested for five exogenous variables: two variants of the short-term real interest rate, the interest rate gap, the tax wedge and productivity. Productivity can affect the Nairu via its influence on wages and prices, and was found to be significant in Nairu estimates for the United States (Stiglitz, 1997, pp. 3-10). The tax wedge proxies the supply-side influence of fiscal policy on the Nairu, and the real interest rate is interpreted as a proxy for the effect of monetary policy.

The short-term real interest rate is the difference between the short-term nominal rate and inflation.[9] Inflation is calculated as year-on-year changes of the GDP deflator level (yoy inflation rate) and as quarter-on-quarter changes (qoq inflation rate). A positive lagged effect of real interest rates on the Nairu can be expected: An increase in real interest rates lowers investment, consumption and – through its influence on the exchange rate – exports. The full impact including multiplier effects should only be felt after more than one year. An analogous reaction is assumed in the case of expansionary monetary policy.[10]

The real interest rate gap is the difference between the neutral real rate and the actual rate. Here we used the short-term real interest rate on the basis of the year-on-year inflation rate. As a proxy for the neutral rate we used the average growth rate of GDP which was 3.2% in the 1970s and 2.2% in the 1980s and 1990s. The higher the interest rate gap, the more expansionary is monetary policy, so that the expected sign of the coefficient is negative.

The tax wedge is calculated as the percentage share of income tax and social security contributions of employees and employers in gross wages.[11] A positive sign is to be expected as an increase in the tax wedge implies an increase in labour costs which in themselves increase the equilibrium level of unemployment.[12]

As the measure for productivity, we use the labour productivity (real GDP divided by the total employment) already tested for in the Phillips curve. Productivity can affect the Nairu if wages and prices do not fully adjust in line with it. For example, if wages do not reflect a given slowdown in productivity growth they give rise to inflationary pressures. Either firms are then able to raise prices accordingly, so that inflation increases without changing the rate of unemployment or firms are unable to raise prices – owing to high competition or low demand or both – in which case inflation will remain unchanged but unemployment will rise. Both cases imply an increase in the Nairu so that one would expect the coefficient to be negatively signed.

All five variables were found to be significant when tested for separately, but not when tested for together. With a coefficient of 0.17 for the tax wedge a one percentage point increase in this variable would have explained an increase in the Nairu by 0.17 percentage points. From 1975 until 1997 the tax wedge increased by 10.5 percentage points. This increase could

[9] The real interest rate was calculated on the basis of data in the IMF's International Financial Statistics for the three largest countries (Germany, France and Italy) that make up 72% of the euro area; starting in 1999 the 3-month euribor was used.

[10] For a recent summary of the timing of monetary policy effects in the euro area using different models, see European Central Bank (2002, pp. 43-53). Symmetry is an implicit assumption. Should the effect of interest rate changes in fact be asymmetric if monetary policy is expansionary or restrictive, the modelling here would imply an averaging of both coefficients. Testing for asymmetry promises to be a fruitful endeavour for future research, especially given recent findings of the ECB to this effect (European Central Bank, 2002, pp. 43-53).

[11] The time series is taken from the European Commission's databank.

[12] To the extent that not only wages but also social security contributions are included, a lower real employee wage is theoretically probable so that labour costs would not increase; cf. Blanchard and Wolfers (2000, p. 13).

explain an increase in the Nairu by 1.8 percentage points (0.17*10.5=1.8) in the same period. But if one includes the real interest rate as an additional exogenous variable, the tax wedge becomes insignificant. A comparison between the two models – one with only the real interest rate as exogenous variable, the other with only the tax wedge – indicates that the real interest rate has higher explanatory power, as the LR-statistic in the first case is below the critical values whereas it is clearly above them in the second case.[13] Productivity was significant and markedly improved the estimate. Consequently the model presented here includes as exogenous variables a real interest rate and productivity. Given that the calculation of a neutral interest rate is fraught with difficulties,[14] we limit our presentation to the real interest rate based on the yoy-inflation rate; the results, however, were very similar when using the interest rate gap. When applying the qoq-inflation rate to deflate the interest rate, the effect of the real interest rate on the Nairu was smaller, but the fit of this model was not as good as that of the other two.

The real interest rate enters the Nairu equation in the first difference (change of the real interest rate). It is significant in lags from three quarters to 15 quarters. The cumulative coefficient is 0.30.[15] A 1 percentage point increase in the real interest rate raises the Nairu by 0.30. It takes 15 quarters (four years) for the effect to fully work through. Given that the real interest rate in the euro area increased by about 10.0 percentage points from 1975 until 1992, according to this model 3.0 percentage points of the increase in the Nairu – and thus half of the increase in the Nairu observed in this period (6 percentage points) – is explained by the increase in interest rates.

Productivity is significant in the Nairu equation in the second differences at three lags (first, fourth and sixth quarter). The cumulative coefficient is -0.06. A slowdown in the speed of productivity improvements by 1 percentage point therefore causes the Nairu to increase by 0.06 percentage points. The effect is significant but small. We interpret it to mean that wages adjust to changes in productivity to a great degree but not fully. The decrease in productivity growth by 1 percentage point from 1975 to 1992 can, according to this estimate, explain an increase in the Nairu by 0.06 percentage points.[16]

The sum of the AR-coefficients of the state equation (unemployment gap) is 0.9772. Its closeness to 1 points to an instationarity of the unemployment gap. The ADF-test, however, rejects the hypothesis of a random walk. The residuals can be interpreted as white noise. The normality test for residuals is accepted for the state equation at the 5% level for the Phillips curve only if a dummy captures an outlier in the first quarter of 1980. The sum of the coefficients of the lagged endogenous variable is 0.9243 and the total effect of the oil price is 0.18. The unemployment gap has a significant negative effect (coefficient = -0.18; t-statistic =

[13] The LR-test was applied to the large model with both variables and to the two small restricted models including the tax wedge and the interest rate respectively.

[14] The greatest difficulty in this respect is that quantifying the neutral rate requires knowledge about the size of the potential growth rate, the computation of the latter, however, requires knowledge about the Nairu which the model tested here is supposed to provide.

[15] If the real interest rate is the only exogenous variable, its cumulative coefficient is 0.37 rather than 0.30. The fit of that estimate is, however, not as good (-2289.7189) as when productivity is included as an additional exogenous variable (-2301.9056). The LR-statistic is thus 12.19, which is above the critical values ($X^2(1)$).

[16] This contrasts with studies for the United States that find the productivity slowdown to be a major cause of the increase in the Nairu in the 1970s and 1980s; see for example Ball and Mankiw (2002). Furthermore, given that euro-area productivity was significant only in the Nairu equation but not in the Phillips curve, the productivity slowdown in Europe did not affect inflation but only unemployment and the Nairu.

-2.73). A widening of the unemployment gap by 1 percentage point lowers inflation in the first quarter by 0.18 percentage points and in the long run by 2.43 percentage points. Chart 1 presents the estimated Nairu and unemployment gap for the euro area.

Chart 1. Kalman-filter estimate of Nairu and unemployment gap in the euro area

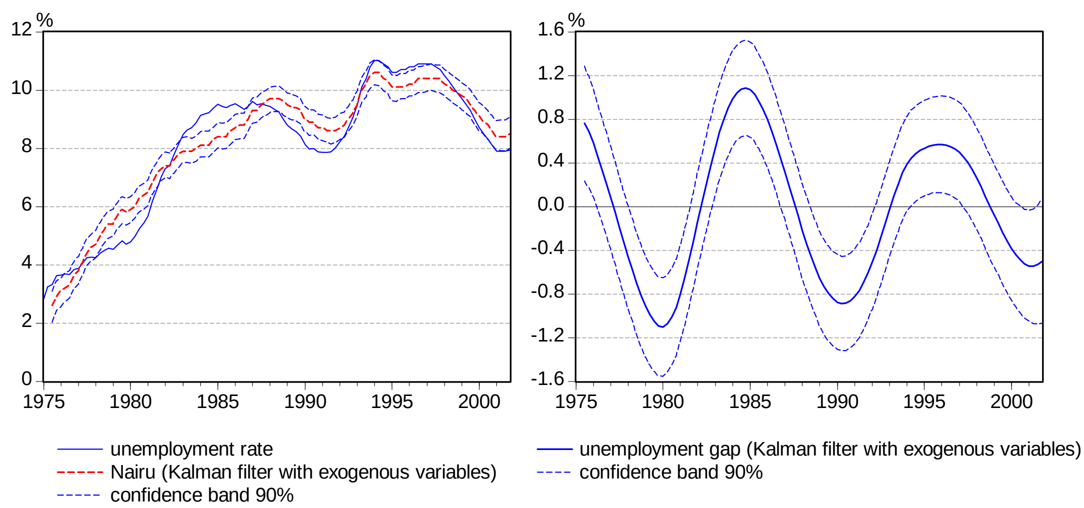

Chart 2. Comparison of the Kalman-filter estimates of Nairu and unemployment gap with and without explicit exogenous variables

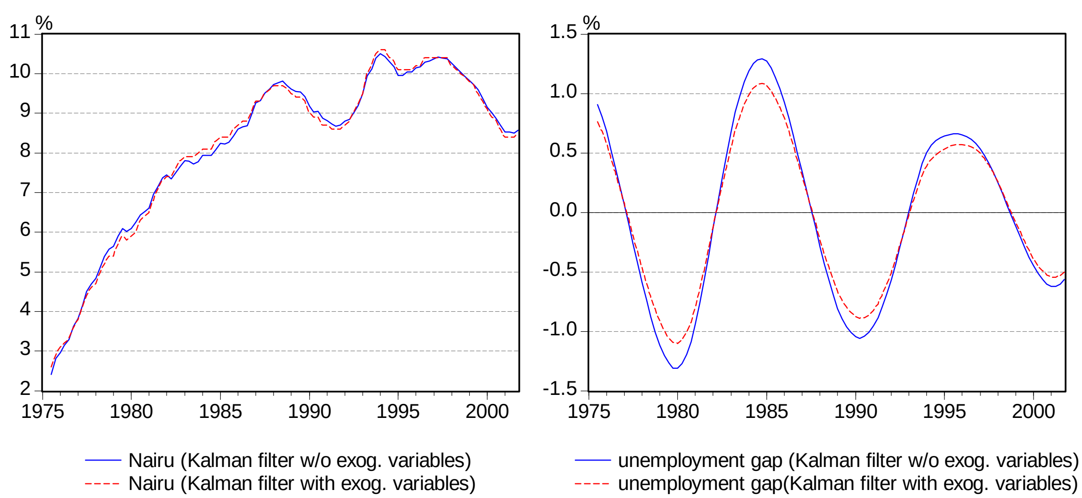

Table 3. Comparison of the validity of Kalman-filter estimates with and without explicit exogenous variables when used in an OLS regression of the Phillips curve

	Kalman filter without exogenous variables	Kalman filter with exogenous variables
Sum of coefficients of inflation	0.9178	0.9180
Sum of coefficients of oil price change	0.0136	0.0136
Coefficient of the unemployment gap	-0.1998	-0.2363
Long-term effect of the oil price	0.17	0.17
Adjusted R^2	0.8970	0.8968
Akaike information criterion	-8.9540	-8.9523
Schwarz information criterion	-8.7530	-8.7513

4. Nairu and short-term real interest rates in the euro area

During the past 30 years the Nairu has changed markedly in the euro area. In the mid-1970s the Nairu was slightly below 3%, by the mid-1980s it had risen to 8.5% and after rising further in the first half of the 1990s to more than 10% it is now measured at 8.4%.[17] Not only did the Nairu vary but in addition there were long periods in which the output gap was negative. Both the Nairu and the unemployment gap affect the living standard: the former via its influence on potential output, the latter through its effect on capacity utilisation. Unemployment gap and Nairu are not independent of each other. To a certain extent the structure of unemployment is hardened or loosened so that the unemployment gap closes as simultaneously the Nairu rises or falls.

The unemployment gap obtained with the Kalman filter can be used to calculate the output gap by using the coefficient of Okun's law. Regressing unemployment on GDP yields a long-term coefficient of 1, meaning that developments of the unemployment gap and of the output gap mirror each other (with opposite signs). The increase in the Nairu by 7.5 percentage points from 1975 to 1994 thus entailed a loss in GDP growth by 7.5%; the unemployment gap of 0.5% from 1994 to 1997 implied furthermore that for this period of four years, GDP was annually 0.5% lower than potential output.

Our hypothesis is that a combination of exogenous shocks, institutions and macroeconomic policy was instrumental in causing the marked increase in the Nairu since the mid-1970s[18]

[17] Like ours, most other economic regressions show a marked reduction in the Nairu since 1996; see for example International Monetary Fund (2001, p. 4). The International Monetary Fund (2001, p.8) uses the Kalman-filter technique (without explicit exogenous variable) to derive a no-supply-shock Nairu that has hovered around 9.5% since the first quarter of 1983 and a Nairu with supply shocks that increased from 8.5% (1983) to almost 11% in 1994 and then slowly diminished to reach slightly more than 8% in the year 2000. An unemployment gap of 1% goes hand in hand with an output gap of 1.7%. The Phillips-curve relation shows that inflation is reduced by 0.5 percentage points in the first year in which the unemployment rate exceeds the Nairu by 1%. The OECD's Nairu (without supply shocks, Turner *et al.* (2001)) climbs from 5.5% in 1980 to 9.2% in 1995 and then falls to reach 8.8% in 1999. The coefficients of the unemployment gap in the Phillips curves of the individual countries (Germany and France 0.2, Italy 0.3) and for the oil price (0.1%) have a similar magnitude as ours. Fitoussi *et al.* (2000) do not estimate a Nairu but do analyse the effect of real interest rates, the oil price and productivity on unemployment in individual countries of the euro area. They find that an increase in real interest rates by 1 percentage point in Germany causes the unemployment rate to increase by 0.2 percentage points (France: 0.4 percentage points; Italy 0.3 percentage points). The coefficient of productivity is much larger than in our estimate (Germany: 0.8; France: 1.6, Italy: 1.2 (Fitoussi *et al*., 2000, p. 250).

[18] Demography can also play a role if the composition of the labour force changes. If the share of those groups that have a high equilibrium unemployment rate rises, the Nairu rises as well. In the EU, the unemployment rate

Institutional factors include the level and duration of unemployment benefits, minimum wages, insider power,[19] restrictions on laying off employees and the like (Layard, Nickell and Jackman, 1991; Blanchard and Wolfers, 2000, pp. 1-33). These institutional factors were enhanced in the 1970s and are likely to have increased equilibrium unemployment to some extent. The role of the individual factors, however, is controversial. Blanchard and Katz (1998, p. 59) for example argue that restrictions on firing make labour markets slower to adjust and lengthen the spells of unemployment but they do not have an effect on the level of unemployment. By contrast, almost all studies find a positive relationship between the duration of unemployment benefits and the level of unemployment (Layard, Nickell and Jackman, 1991; Ball, 1999, pp. 189-236; and Fitoussi et al., 2000, pp. 237-310). Changes in labour market institutions alone do not, however, appear to be sufficient to explain the marked increase in unemployment in the countries of the euro area since the early 1970s (Blanchard and Katz, 1998, p. 68). Machin and Manning (1999, p. 3107) assert that:

> The basic problem is here is that labour market institutions have not changed enough over the past 30 years to provide a plausible explanation of the rise in unemployment. (Machin and Manning, 1999, p. 3107)

Similarly, Blanchard and Wolfers (2000, p. 2) argue that:

> Many of these institutions were already present when unemployment was low (and similar across countries), and, while many became less employment-friendly in the 1970s, the movement since then has been mostly in the opposite direction. Thus, while labour market institutions can potentially explain cross country differences today, they do not appear able to explain the general evolution of unemployment over time. (Blanchard and Wolfers, 2000, p. 2)

Many recent studies therefore reach the conclusion that macroeconomic shocks played a key role in bringing about the sharp increase in unemployment. Four shocks dominate: the two oil price shocks from 1973 to 1974 and from 1980 to 1981, the marked slowdown in productivity growth in the 1980s relative to the 1970s and a higher level of international real interest rates.[20]

The euro price of oil tripled from 1973 to 1974. The second oil price shock took place in 1979 to 1980: in 1981 the euro price of oil was more than three times as high as in 1978 and exceeded its 1971-level tenfold. The annual productivity increase slowed from 5% in the

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of those aged 15-24 years is more than twice as high than the unemployment rate of those aged 25-54 years. In 2001 the unemployment rate of the 15- to 24-year olds was 13.9% (1990: 16.1%) in the EU, the unemployment rate of the 25- to 54-year olds 6.5% (1990: 6.7%) (OECD Employment Outlook, 2002, pp. 307-309). In the 1970s labour markets in Europe experienced a swelling of the group of first-time employees as did those in the US. In the US the share of the young (16-24 years) in the labour force rose from 17% in 1960 to 24% in 1978. This explains a small part of the increase in the Nairu in that country; cf. Ball and Mankiw (2002, pp. 12ff.) and the references therein. The subsequent integration of inexperienced workers into the work force will have led to a reduction in the Nairu by the early 1980s.

[19] Within the insider/outsider model, only insiders, i.e. employees, take part in the wage bargaining process so that unemployment does not lead to lower wages. This approach cannot explain long-term unemployment as for example newly founded enterprises do not have any employees to consider (Spahn, 1999, p. 179). The bargaining power of insiders can however explain a longer duration of unemployment and which in turn tends to raise the Nairu (see below).

[20] Cf. Blanchard and Wolfers (2000); Layard, Nickel and Jackman (1991); Clarida et al. (1998) according to Layard, Nickel and Jackman (1991) changes in the Nairu result from relevant institutions combined with great shocks that hit the economy; Clarida et al. (1998, p. 1034) find a policy break after 1979 in 63 countries.

1960s to 3% in the 1970s and only 2% in the 1980s and 1990s. International real interest rates climbed by 5 percentage points from 1975 to 1990 (Fitoussi *et al*., 2000, pp. 237-310).

Whereas the slowdown in productivity growth, the oil price shocks and the increase in international real interest rates were experienced by all countries – albeit to different degrees – a marked difference between the monetary policies pursued by the individual central banks can be observed. The US Federal Reserve lowered interest rates rapidly when an economic downturn presented itself, thus containing the strength and duration of a given crisis.[21] In consequence, an increase in unemployment remained a temporary phenomenon. Monetary policy in the countries of the current euro area in contrast maintained a restrictive stance longer. Economic downturns were more pronounced and the weak growth was not compensated for in subsequent years. As a result, the growth path in the European economies was lower and more flat than would have corresponded to their production possibilities.

A major difference between studies dealing with the development of unemployment in EU countries is whether or not they consider this contrast in the monetary policy reaction: Layard, Nickel and Jackman (1991) and Clarida et al. (1998, pp. 1033-1067), for example, analyse the effects of shocks and in this context discuss the level of world interest rates; they do not, however, examine the macroeconomic policies in the individual countries. By contrast, Fitoussi *et al.* (2000, pp. 237-310), Ball and Mankiw (2002), Ball (1999, pp. 189-236) and Blanchard and Katz (1997, pp. 51-72) relate the marked increase in unemployment and the fact that it remained high to the restrictive stance of monetary policy. Our results support the hypothesis put forth by Ball (1999, pp. 189-236) that monetary policy played a decisive role in whether unemployment hardened in individual countries:

> In some countries, such as the United States, the rise in unemployment was transitory; in others, including many European countries, the Nairu rose and has remained high ever since. I argue that the reaction of policymakers to the early-1980s recessions largely explain these differences…In countries where unemployment rose permanently, it did so because policy remained tight in the face of the 1980s recessions. (Ball, 1999, p. 190)

The estimation results sketch the following picture of the developments during the past three decades: In the mid-1970s, the Nairu was just below 3% and there was a noticeable positive unemployment gap given actual unemployment of barely 1%. This set a wage-price spiral in motion that was accelerated by the first oil price shock. By the end of the 1970s the Nairu had risen to about 6%. Several factors are likely to have contributed to this increase: institutional changes in the early 1970s, the duration of the oil price shock and the concomitant hysteresis effects on the labour market as well as the productivity slowdown, which represented an additional supply shock. Nevertheless, the decline of productivity growth relative to the 1960s by 1 to 2 percentage points can account for merely 0.06 to 0.12 percentage points in the increase in the Nairu. Monetary policy was expansionary during this period. Real interest rates had fallen from 1% in 1973 to -3% in 1975 and lowered the Nairu by around 1.2 percentage points. The increase in the Nairu by 3.4 percentage points from 1975 to 1980 is therefore largely the result of institutional factors not explicitly accounted for in our regression.

Quite a different picture emerges for the 1980s: At that time monetary policy was decisively restrictive. The short-term real interest rate rose from 1% at the beginning of 1980 to 5.4% in

[21] The Fed has acted in this fashion active since the late 1970s. During the 1970s it had been more passive and thus contributed to the simultaneous increase in inflation and unemployment; cf. Beyer and Farmer (2002).

1989, thereby reducing economic growth and resulting in an increase in both actual unemployment and in the Nairu. Taking into consideration the lagged effect of the increase in interest rates in the second half of the 1970s real interest rates led to an increase in the Nairu until the end of the 1980s by 1.9 percentage points (6.2 percentage points * 0.3 = 1.9 percentage points). This is 60% of the entire increase in the Nairu during the 1980s. By contrast, the productivity slowdown did not have a measurable effect. In the first half of the 1990s a further increase in the Nairu by 1.2 percentage points to 10.5% coincided with an increase in real interest rates by around 2 percentage points. This increase in interest rates can account for half of the increase in the Nairu.

Since the mid-1990s, the Nairu has declined by 1.4 percentage points. This decline can also be in part explained by the movement in real interest rates. The latter fell by 2.4 percentage points thereby contributing 0.75 of a percentage point to the Nairu's reduction. The other part of the decline is not explicitly accounted for by our regression. Institutional changes in the labour market since the 1980s most likely played a role in bringing about this decline.

All in all, monetary policy was expansionary and partly countered the increase in the Nairu caused by institutional labour market changes in the early 1970s. In the 1980s monetary policy became markedly restrictive and induced a large increase in the Nairu which was even greater due to the lagged effect of the move away from an expansionary stance since the mid-1970s. In the 1990s real interest rates initially contributed to a further increase in the Nairu and decreased since the mid-1990s, thereby generating a decline in the Nairu.

To what extent are changes in short-term real interest rates to be attributed to monetary policy? To what extent could a different monetary policy in the countries of the euro area have permitted a lower Nairu and thus higher potential output growth?

Monetary policy certainly had to act restrictively to contain the inflationary pressures of the 1970s and to bring inflation back to acceptable levels. A reduction in inflation is brought about through an increase in unemployment, so that a temporary increase in the rate of unemployment was unavoidable during the 1980s. The pressure unemployment exerts on inflation, however, diminishes over time. Unlike the central banks in Europe, the US Federal Reserve took this point into consideration with the consequence that the increase in unemployment remained a temporary phenomenon in the United States, whereas it hardened in the countries of the euro area, thus becoming a more permanent phenomenon. This is evident when one compares the timing of policy reaction, inflation slowdown and unemployment increase around the time of recessions. A correlation test for the period of 1980 until 2001 also shows that whereas the Fed reacts promptly to a change in unemployment, the European central banks hardly react to changes in unemployment at all.[22]

Chart 3 shows these different monetary policy reactions in the US on the one hand and in the euro area on the other. The Federal Reserve lowered nominal interest rates as unemployment started to rise, the European central banks stayed on a restrictive course much longer. The gain in the shape of an additional reduction in inflation was small. This is not surprising as econometric analyses[23] indicate that the disinflationary effect of unemployment decreases

[22] The correlation between short-term nominal interest rates and the unemployment rate (both in first differences) is significantly negative for lags zero and one in the case of the United States; in the case of the euro area only lag zero is significant and the coefficient is much smaller; see also the empirical analysis by Ball (1999, pp. 189-236).

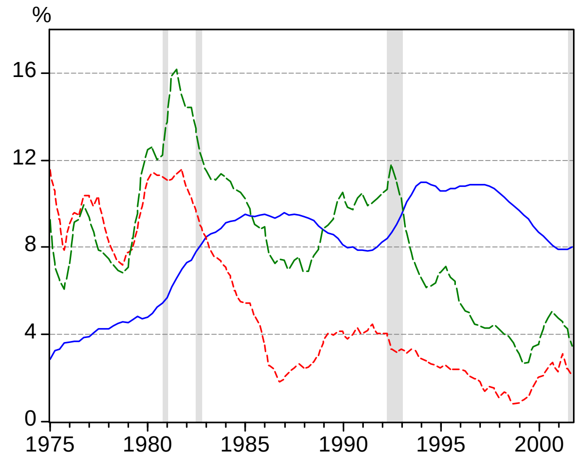
[23] Impulse-response analyses show that in the euro area an increase in unemployment lowers inflation from quarters three to 12; in the United-States the effect is significant only in the first seven quarters.

over time. One reason for this is that the long-term unemployed lose their ability to compete with employees. In addition, as investment declines in response to restrictive monetary policy the capital stock becomes relatively smaller, further lowering the demand for labour.

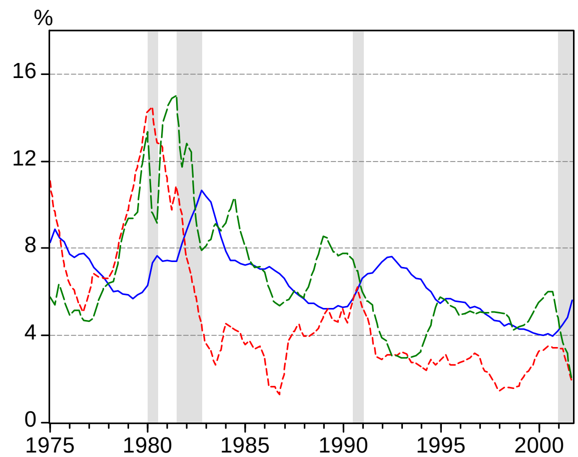
The diminishing effect of unemployment on inflation over time implies an increase in the equilibrium unemployment rate, the Nairu. This solidification of unemployment, also called hysteresis, can have many causes. Its main aspect, however, is that the number of long-term unemployed persons rises and that the latter exert less of an influence on labour market developments and on wages in particular than do the short-term unemployed. There are several reasons why the long-term unemployed have a hard time finding a job:

- The human capital of the unemployed tends to diminish (Blanchard and Summers, 1991, pp. 235-246; Pissarides, 1992, pp. 1371-1391).
- The testing of potential employees is not costless. Therefore employers rank potential employees according to the frequency and duration of unemployment spells and favour those with fewer occurrences of unemployment (Lockwood, 1991, pp. 733-753; Blanchard and Diamond, 1994, pp. 417-434).
- Unemployed persons lose contact with those who are employed, inter alia because they lack sufficient financial resources to participate in certain social activities or because they feel stigmatised. As a consequence, they do not even find out about some job offers and are not considered for some jobs. Machin and Manning (1999, p. 3120) found that about one-third of all jobs in the UK are filled with friends and relatives of those already employed in the firm. This is a cost-effective way of hiring since it is unlikely that an employee will put forth someone unqualified to do the job.
- A long period of high unemployment can raise the social acceptance of unemployment, which could increase the reservation wage of the unemployed (Lindbeck, 1995).
- Rising long-term unemployment increases the political pressure to implement public job creation schemes, which in turn may increase unemployment by reducing the negative aspects of unemployment (Blanchard and Katz, 1997, pp. 68/69); on the other hand, they tend to reduce the Nairu by preserving the human capital of the persons involved.

Chart 3
Monetary policy reactions to unemployment
in the Euro Area and the United States



unemployment rate (EU-11)
HICP inflation rate (EU-11)
nominal short-term interest rate (EU-3, after 1999 EU-11)



unemployment rate (USA)
HICP inflation rate (USA)
nominal short-term interest rate (USA)

The shaded areas mark recessions

If, for the reasons cited above, the long-term unemployed are not competition for those holding a job, they do not exert downward pressure on wages.[24] Within the efficiency-wage model this can be easily shown. The main hypothesis of this approach is that wages are set at a level inducing workers to be highly productive (Shapiro and Stiglitz, 1984, pp. 433-444). This level is dependent on the job prospects in case of job loss. The better the job prospects, the higher are efficiency wages (and in consequence inflation). If the long-term unemployed are not seen as competition for the employed, the short-term unemployed figure in the job prospects and the effect that the long-term unemployed may have on wages disappears.

A further mechanism causing hysteresis in the labour market is the downward adjustment of the capital stock which reduces labour demand.[25] The theoretical model that serves as the backdrop for the analysis, is the standard model of modern macroeconomic analysis slightly modified in the determination of potential output to allow for hysteresis in the labour markets.[26]

With this modification, disinflation may affect the level of potential output and thereby lower the economy's growth path (albeit not its slope). In other words, long-term monetary nonsuperneutrality is allowed for.[27] Take the example of monetary policy increasing real interest rates to reduce inflation. This causes unemployment to rise. If real interest rates are not lowered once unemployment has started to rise, then unemployment spells will last relatively long and the number of long-term unemployed will increase. If the human capital of the latter diminishes or the history of unemployment reduces the ability to find a new job, the effective labour supply declines (the Nairu increases). As a result, labour market equilibrium will now involve a lower level of employment. This specification implies that nonsuperneutrality does not require the Fisher relation to be violated in the long run. An increase in interest rates maintained beyond the short term raises the Nairu and the Nairu does not fall back to its initial level when the initial level of real interest rates is reached.

Unfortunately, our specification of the Kalman filter precludes the possibility of finding a long-term effect of monetary policy on the Nairu unless the Fisher relation is rejected. This is because symmetry is assumed by design. If the Nairu is found to increase as a reaction to a rise in real interest rates, it will decline by the same amount once real interest rates fall to their initial level. A rejection of the Fisher relation is found in numerous empirical studies and is not far-fetched (Bullard and Keating, 1995, pp. 477-96; Weber, 1994, pp. 67-117). Nonetheless we find the transmission of long-term nonsuperneutrality via hysteresis on the

[24] Many studies on the UK find empirical evidence that only short-term unemployed individuals and not long-term unemployed individuals have an influence on the wage bargaining process; cf. Machin and Manning (1999, pp. 3085-3139) and the references cited therein.

[25] "The final persistence mechanism operates though the capital stock...Suppose there is an increase in wage pressure that shifts the wage-setting schedule, *WW*, up. Equilibrium employment falls. Nevertheless the intersection of medium-run labour demand, *NN*, with *WW* now lies above the long-run labour demand schedule; *NN**, along which capital is allowed to vary. The mechanism that brings the economy back to long-run equilibrium is capital decumulation which shifts *NN* in until *NN*, *NN**, and the new *WW* curves all intersect at the same point (Bean, 1997, p. 93)."

[26] This standard four-equation model is found in Clarida, Gali and Gertler (1999, pp. 1661-1707); see also McCallum (2001, pp. 258-262), Mankiw (2001, pp. C45-61) and Taylor (1997, pp. 233-235); Mankiw (2001, pp. C45-61) shows one way of modifying the equation for potential output to allow for hysteresis in the labour markets.

[27] Monetary superneutrality is the proposition that a permanent change in the rate of money growth does not affect the level of output in the long run. By contrast monetary neutrality is taken to refer to the effect of a change in the *level* of the money supply on the output level.

labour market theoretically more compelling. Given the limitations of our Kalman-filter programme we therefore take a two-step approach to find support for the hypothesis of long-term nonsuperneutrality. First, we interpret our Kalman-filter analysis as showing that short-term real interest rates have an impact on the level of the Nairu. Second, we use a bivariate structural VAR to test for superneutrality in the euro area.

We include in our bivariate structural VAR-model the inflation rate and output. Both variables are integrated of order 1. We find that for the examined time period of 1971 to 2001, superneutrality is rejected. A change in the level of the inflation rate is seen to have a positive short-term effect on output growth that is not reversed in later periods, so that the level of output is changed permanently.[28] This corresponds with the tests performed by Bullard and Keating (1995, pp. 477-496) and Weber (1994, pp. 67-117) for individual countries of the euro area, according to which long-run superneutrality with respect to the level of real output is rejected for a wide variety of identifying restrictions across the G7 economies. They also used bivariate VARs in differenced money growth and differenced real output with a data set that goes back to the 1960s.

It is important to note that in this context the real effects of monetary policy do not hinge on money illusion.[29] In the words of noble prize laureate Robert M. Solow: “The long-run aggregate supply curve may be vertical, but its location is endogenous to macroeconomic policy (Solow, 1999, p. 11)”.

5. Conclusion

Our econometric analysis supports the hypothesis that the euro area’s Nairu varies over time. Given the lack of comparable data on labour market institutions we chose an econometric technique that does not require such detailed information. The Kalman-filter estimates a time-variable Nairu using information provided by the simultaneously estimated Phillips curve, without requiring the individual determinants of the Nairu to be specified. These are implicitly contained in the estimation. It furthermore offers the possibility of specifying individual exogenous variables and quantifying their effect. Short-term real interest rates proved to have a significant influence on the Nairu.

Our econometric analysis produced the following results: In the countries of the euro area, the Nairu rose from around 3% in 1975 to more than 6% in 1980 and 10.4% in 1994; in 2001 the Nairu was 8.5%. A change in short-term real interest rates by 1 percentage point leads to a change in the Nairu by 0.3 percentage points. In the Phillips curve, the unemployment gap has a significant negative effect: If the gap increases by 1 percentage point, inflation decreases by 0.18 percentage points in the first quarter and by 2.43 percentage points in the long run. A change in the euro price of oil by 1% produces a change in the inflation rate by 0.18 percentage points. These results are similar to those of other studies that estimate a time-varying Nairu.

The relatively large changes in the Nairu over time imply first that the unemployment gap and the output gap are relatively small. These hardly ever exceed 1%. By contrast, the (International Monetary Fund, 2001, pp. 4-15) finds output gaps with and without supply shocks that exceed 2% in both directions for a period of several years. Gerlach and Smets, (1999, pp. 801-812) also calculate an output gap using the Kalman filter and similarly find it

[28] The results of this analysis are presented in detail in Logeay and Tober (2003, forthcoming).

[29] Cf. Bean (1997, pp. 81-111), Solow (1999 and 2000, pp. 1-12), and Tobin (1993, pp. 45-66).

to be in excess of 2% for a period of several years and in 1975 it even surpasses 4%.[30] The second conclusion to be drawn from our analysis is that the real influence of macroeconomic policy is relatively large: A restrictive (expansionary) monetary policy not only increases (reduces) current unemployment but also the Nairu and can thus exert a long-term real effect on the economy.

It follows that macroeconomic policy should support private economic forces to fully exploit the euro area economies' potential growth so as to prevent an increase in unemployment and subsequently an increase in the Nairu, which in turn would reduce that same potential.[31] Once long-term unemployment and the uncounted, hidden reserve of the labour force have increased, measures to increase employment and potential output are more complicated, albeit not impossible. Macroeconomically, wage restraint is required to increase profitability and investment, combined with expansionary macroeconomic policies that ensure that wage restraint translates into lower real wages and higher returns on investment rather than lower aggregate demand and falling prices.

If the economy reaches the boundaries of inflation-free growth earlier than anticipated by policy-makers, interest rates can be increased and inflationary tendencies nipped in the bud before they become entrenched in expectations. The economy is neither a string that cannot be pushed, nor is inflation a genie unlocked from its bottle. If, however, policy-makers maintain an inappropriate policy for several years, a reversal will be more difficult. In the case of a policy stance that is too expansionary, inflation expectations will adjust. To regain credibility and reduce inflation expectations may then require a long period of disinflation characterised by depressed economic activity. Similarly, a central bank that was too restrictive for several years might not only have pushed up unemployment and reduced inflation, but also caused cyclical unemployment to persist and take the shape of structural unemployment.

[30] The effect of the unemployment gap on inflation within the Phillips curve is only 0.8 percentage points and thus much smaller than ours (Gerlach and Smets, 1999, pp. 801-812).

[31] Fischer (1997, pp. 111-115) argues in a similar fashion and the International Monetary Fund (2000, pp.78-80) recently stressed the potential negative effect of underestimating potential output.

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APPENDICES TO THE NAIRU ESTIMATION

1. Modelling Technique

A state-space model finds a relation between observed time series and an unobserved one (called the state variable). The observation equation(s) (also called measurement equation) specifies this relation, whereas the transition equation(s) (also called state equation) specifies the dynamic process driving the state. Both equations together define the space within which the state is allowed to move. The Kalman filter is an algorithm that estimates the state, given the observable variables and the specified state-space model.

In an AR(2)-process the value of a variable in time *t* depends on its values in the previous two periods and a disturbance term with mean zero: $X_t \sim AR(2) \Leftrightarrow X_t = ar_1 X_{t-1} + ar_2 X_{t-2} + \varepsilon_t$, where ε_t is white noise.

A process is a local linear process ($X_t \sim LLM$), if two iid- white noise e_t and v_t exist, so that:

$X_t = X_{t-1} + trend_t + e_t$ and $trend_t = trend_{t-1} + v_t$. This approach makes it possible to model the Nairu either as a random walk with or without drift (I(1)-variable) or as a I(2)-variable. It is therefore more general than the random-walk approach. In addition, one can test whether the random-walk assumption is too restrictive for the Nairu by constraining $Var(\varepsilon^{trend})$ to be zero. Our calculations indicate that this is the case.

The estimated state-space model is written as follows:

$$
\text{(A1)} \quad
\begin{aligned}
&(u - u^*)_t = ar_1 (u - u^*)_{t-1} + ar_2 (u - u^*)_{t-2} + \varepsilon_t^{ugap} \\
&NAIRU_t = NAIRU_{t-1} + trend_t + \delta d(Z^{nairu}{}_t) + \varepsilon_t^{nairu} \\
&trend_t = trend_{t-1} + \varepsilon_t^{trend} \\
&u_t = (u - u^*)_t + NAIRU_t \\
&\pi_t = \beta_0 (u - u^*)_t + \gamma X^{phillips}{}_t + \varepsilon_t^{\pi}
\end{aligned}
$$

For technical reasons related to the programme used, the system has to be transformed. The Nairu equation is transformed as follows:

$$
\text{(A2)} \quad
\begin{aligned}
&d(NAIRU_t) = trend_t + \varepsilon_t^{nairu} + \delta d(Z_t) = d(NAIRU_t^{Implicit}) + \delta d(Z_t) \\
&\Rightarrow NAIRU_t = NAIRU_t^{Implicit} + \delta Z_t \quad , \quad \text{where } NAIRU_t^{Implicit} \sim LLM
\end{aligned}
$$

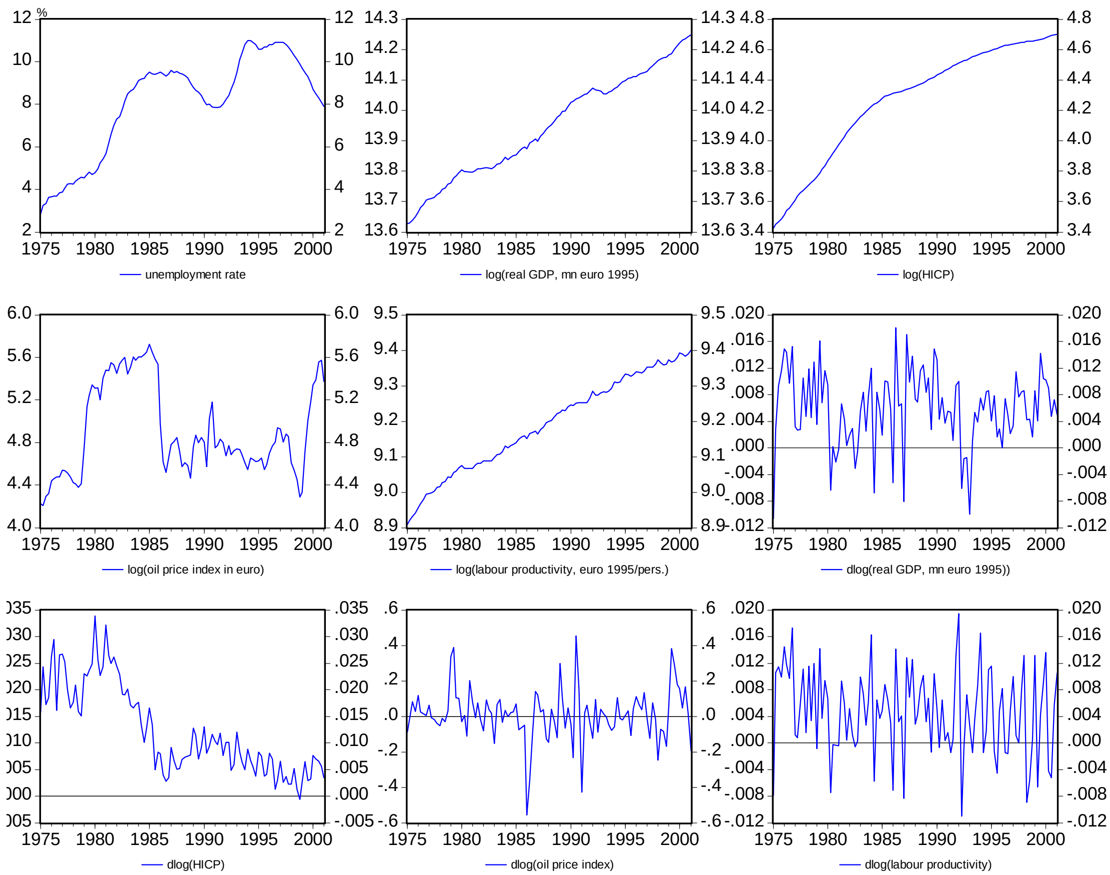
The term *Implicit* refers to the part of the Nairu that is not explicitly explained by exogenous variables; in our case this includes, for example, institutional factors. The equations are therefore:

$$
\text{(A3)} \quad
\begin{aligned}
&(u - u^*)_t = ar_1 (u - u^*)_{t-1} + ar_2 (u - u^*)_{t-2} + \varepsilon_t^{ugap} \\
&NAIRU_t^{Implicit} = NAIRU_{t-1}^{Implicit} + trend_t + \varepsilon_t^{nairu} \\
&trend_t = trend_{t-1} + \varepsilon_t^{trend} \\
&u_t = (u - u^*)_t + (NAIRU_t^{Implicit} + \delta Z^{nairu}{}_t) \\
&\pi_t = \beta (u - u^*)_t + \gamma X^{phillips}{}_t + \varepsilon_t^{\pi} \\
&\text{memo.}: NAIRU_t = NAIRU_t^{Implicit} + \delta Z^{nairu}{}_t
\end{aligned}
$$

A constant cannot be estimated for the Nairu equation.[32] The constant was therefore set to zero, implying that the unemployment gap oscillates around zero.

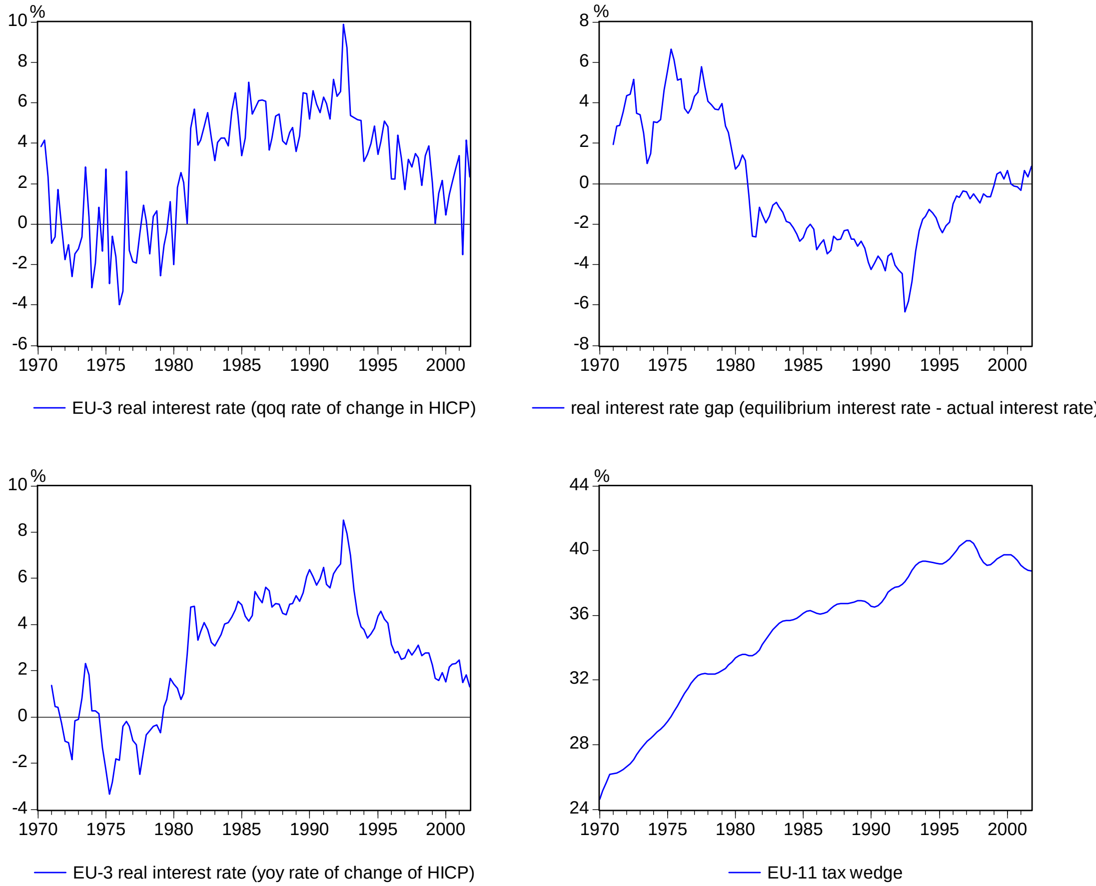
A2. Data

Chart 1
Presentation of the data in levels and differences



[32] This means that there are an infinite number of pairs of the variables (nairu-c, (u-u*)+c), that produce the same result. Here the programme sets c=0 (=> E(u-u*)=0).

Chart A2. Potential exogenous variables affecting the Nairu



A3. Test Results

Chart A3. Nairu and unemployment gap according to the HP-filter

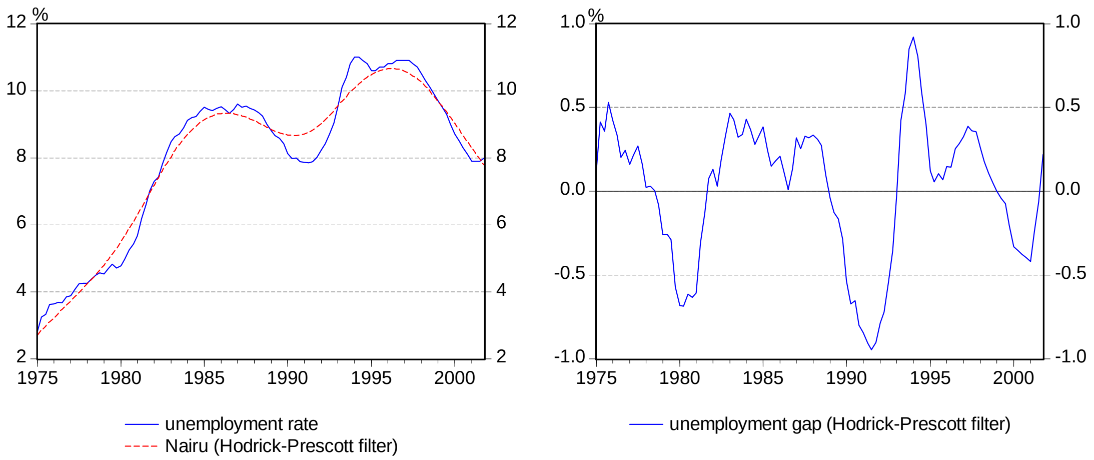


Table A1. Output of the OLS-estimate of inflation based on an HP-filtered unemployment gap

Test Equation:
Dependent Variable: D(CPI)
Method: Least Squares
Date: 09/11/02 Time: 16:32
Sample: 1975:1 2001:4
Included observations: 108

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(CPI(-1))	0.4053	0.0808	5.0191	0.0000
D(CPI(-3))	0.1740	0.0781	2.2278	0.0282
D(CPI(-4))	0.3321	0.0945	3.5155	0.0007
D(CPI(-5))	-0.2463	0.0872	-2.8234	0.0058
D(CPI(-8))	0.2690	0.0695	3.8719	0.0002
HP_Ugap	**-0.1850**	**0.0769**	**-2.4053**	**0.0180**
D(POIL_EURO)	0.0081	0.0020	3.9940	0.0001
D(POIL_EURO(-3))	0.0080	0.0021	3.8924	0.0002
D(POIL_EURO(-4))	-0.0055	0.0018	-3.0332	0.0031
D(POIL_EURO(-5))	0.0029	0.0016	1.7495	0.0833

R-squared	0.8903	Mean dependent var	0.0121
Adjusted R-squared	**0.8802**	S.D. dependent var	0.0083
S.E. of regression	0.0029	Akaike info criterion	**-8.7837**
Sum squared resid	0.0008	Schwarz criterion	**-8.5353**
Log likelihood	484.3186	Durbin-Watson stat	2.0826

An F-Test on the sum of the coefficients of inflation in the OLS regression (=0.9342) rejects the hypothesis that they are equal to one (Prob=0.2%). Changes in the euro price of oil have a significant and positive effect on inflation (0.21).[33] An increase in the oil price by 1% results in a rise in the HICP by 0.2% in the long run. Productivity turns out to be insignificant – the exclusion-F-test has a probability of 29.6% – and was therefore omitted from the equation.[34] This implies that changes in productivity do not affect inflation. The HP-filter generated estimate of the unemployment gap has a significant negative effect on inflation.

The residuals are normally distributed (JB-Prob = 5.2%) white noise (Q(4)-Prob = 78.9%),[35] and the equation can be viewed as stable, since the CUSUM tests reject the hypothesis of structural breaks. To compare the different models estimated we use the adj. R^2, Akaike and Schwarz statistics The adjusted R^2 – also called centred R^2– shows the share of the variance of the endogenous variable explained by the model after correcting for the number of exogenous variables (adj.R^2=1: perfect fit, adj.R^2=0: the model is not superior to a model that has only a constant as an exogenous variable). Akaike- and Schwarz-criteria are statistics based on the log-Likelihood. As with the adj. R^2, they contain a factor that punishes for each additional explanatory variable. They permit the testing of hypotheses that are not nested, i.e. hypotheses that are not embedded in a larger model. The statistic is smaller and thus the model is better.

[33] The long-term effect of the oil price on inflation is calculated with the following formula:

$$\frac{\sum \text{coefficients of the oil price index}}{1 - \sum \text{coefficients of the HICP}}$$

[34] A similar result was obtained by other studies such as Turner et al., (2001), pp. (171-216 and Laxton et al., 1998).

[35] Q(4)-Prob is the probability associated of the Q(4)-Statistic (test of autocorrelation to the fourth order). JB-Prob is the probability associated with the Jarque-Bera-Statistic (test of normality).

A4. Unit Root Tests

The unit root tests are ADF tests. The following table shows the test results:

Table A2. ADF-Tests

1975-2001					
	H0: I(2) vs I(1)				
variable	t-stat	specification	lags	critical values (10,5,1%)	conclusion
HICP	-1.86	c, 80q1	1,2,3	-3.492/-2.888/-2.581	H0 not rejected
unemployment rate	-3.41	-	1,4	-2.585/-1.943/-1.617	H0 rejected
real GDP	-8.44	c	-	-3.492/-2.888/-2.581	H0 rejected
labor productivity	-9.51	c	4	-3.492/-2.888/-2.581	H0 rejected
oil price index	-7.01	-	2,3,5	-2.585/-1.943/-1.617	H0 rejected
real wage	-2.16	-	1,2,3	-2.585/-1.943/-1.617	H0 not rejected at 1%, rejected at 5, 10%
	H0: I(1) vs I(0)				
variable	t-stat	specification	lags	critical values (10,5,1%)	conclusion
HICP	-2.05	c,t,80q1	1,3,5	-4.046/-3.452/-3.151	H0 not rejected
unemployment rate	-1.81	c	1,4,5	-3.492/-2.888/-2.581	H0 not rejected
real GDP	-2.77	c,t	1,2	-4.046/-3.452/-3.151	H0 not rejected
labor productivity	-2.33	c,t	4	-4.046/-3.452/-3.151	H0 not rejected
oil price index	-2.69	c	1,2,3,4	-3.492/-2.888/-2.581	H0 not rejected
real wage	-2.29	c,t	4	-4.046/-3.452/-3.151	H0 not rejected
real nominal short-term interest rate (qoq)	-1.79	c	1,2,3	-3.492/-2.888/-2.581	H0 not rejected
real nominal short-term interest rate (yoy)	-2.13	c	1	-3.492/-2.888/-2.581	H0 not rejected
real interest rate gap	-1.93	-	1	-2.585/-1.943/-1.617	H0 not rejected at 1%, rejected at 5, 10%
wage wedge	-2.39	c	1,2,3,4,5,6,8	-3.492/-2.888/-2.581	H0 not rejected
unemployment gap (KF, without Exo)	-5.3	-	1,2	-2.585/-1.943/-1.617	H0 rejected
unemployment gap (KF, with Exo)	-5.23	-	1,2	-2.585/-1.943/-1.617	H0 rejected

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