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# The Equilibrium Rate of Unemployment and the Real Exchange Rate: An Unobserved Components System Approach

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**Abstract**

We set up and estimate a structural unobserved components open economy model for the rate of unemployment and the real exchange rate in Sweden. This approach enables us to simultaneously determine changes in both cyclical and equilibrium rates. Our results show that the Natural Rate/NAIRU has increased by approximately 1.5 percentage points since the 1970s, driven by a depreciation of the equilibrium exchange rate, changes in taxes, active labor market policies and demographic factors. Thus, the results indicate that the dramatic changes in the Swedish unemployment rate during the 1990s mainly was a cyclical phenomenon. After five devaluations in the 1970s and early 1980s the krona was allowed to float on 19 November 1992. The depreciating trend continued during the floating rate period. Our model successfully explains this development as being driven by changes in terms of trade, demographics and structural government deficits. The change in the rate of inflation is found to be quite sensitive to the unemployment gap. An increase in cyclical unemployment by 1 percentage point will reduce inflation by approximately 0.6 percentage points within a year.

KEY WORDS: Natural Rate, NAIRU, equilibrium real exchange rate, Phillips curve, unobserved-components model.

JEL CLASSIFICATION: C32, E24, E31, E32, F31, F41.

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## 1 Introduction

After having enjoyed decades of low unemployment the Swedish unemployment rate increased dramatically in the early 1990s. The rate of open unemployment rose from approximately 1.5 per cent in 1990 to over 9 per cent two years later. A thorough description of the development and economic policy during this period is given in Jonung (2003).

The rapid rise in unemployment immediately raised questions regarding to what extent the development should be attributed to structural changes or to a lack of demand.

Holmlund (1993) and Elmeskov (1994) address the issue by recursively estimating simple Phillips curves and imposing equilibrium restrictions in order to derive a measure of the NAIRU and the unemployment gap. Their results do not indicate any substantial changes in the NAIRU. Forslund (1995) estimates a structural open economy model for wage and price setting under imperfect competition and solves it for the NAIRU. He finds evidence of a more noteworthy increase in the NAIRU. Assarsson and Jansson (1998) and Lindblad (1997) estimate different structural unobserved components models allowing for hysteresis and find robust evidence for substantial hysteresis in Swedish unemployment rates and a large increase in the permanent component of the unemployment rate. Apel and Jansson (1999) estimate a different unobserved components model and find that the NAIRU increased during the first half of the 1990s. Turner et al. (2001), who also model NAIRU as a stochastic trend, show that the Swedish NAIRU increased by nearly 3.5 percentage points from 2.4 per cent in 1980 to 5.8 per cent in 1995. In 1999 the level was the same as in 1995.

In 1997 the unemployment rate started to decline and has now, as it seems, stabilized around 4-5 per cent. The central question, if the change reflects a change in NAIRU or a narrowing of the unemployment gap, is still important. Turner et al. (2001) and updates of the Apel and Jansson (1999) model indicate that most of the reduction is due to a smaller unemployment gap.[1]

A quite common assumption when analyzing unemployment is that the economy is closed. Joyce and Wren-Lewis (1991), Layard, Nickell and Jackman (1991) and Bean (1994) show that the NAIRU is not identified in an open economy unless the foreign sector is modeled. It is straightforward to show that in an open economy the unemployment rate will be, among other factors, driven by the real exchange rate. The Swedish real exchange rate gradually weakened between the late 1970s and the early 1990s, and the movements during this period were large. Since late 1992 the Swedish krona has depreciated substantially.

As in the case of unemployment, a central question is to what extent the depreciation is due to structural changes. Alexius (2001) uses a cointegration framework and concludes that movements in the SEK/DEM equilibrium real exchange rate (REER) are dominated by out-of-equilibrium fluctuations. This finding is corroborated by Bergwall (2002) for a larger set of fundamental vari-

[1] The recent international empirical literature regarding NAIRU is surveyd in Turner et al. (2001) and Ball and Mankiw (2002).

ables.[2]

The purpose of this paper is to give an up to date answer to the question whether the changes in unemployment and real exchange rate could be regarded as movements in the NAIRU and the REER or in the output gap. In order to do this, we take the unobserved components model of e.g. Salemi (1999) a step forward by setting up an open economy framework and simultaneously estimate the rate of unemployment and real exchange rate.

The paper is organized as follows. First we very briefly present a simple open economy model for wage and price setting under imperfect competition and combine it with an exchange rate model. This gives us two equilibrium relationships: one for the unemployment and one for the real exchange rate. It also gives us two cyclical relationships: an expectations augmented Phillips curve and a cyclical real exchange rate. Second, these equations are combined with a statistical model for the cyclical behavior of unemployment in order to get an empirical model. Third, we estimate the system simultaneously. Finally, we sum up.

# 2 Theoretical discussion

In this section, we present a small open economy model that can serve as a basis for analyzing movements in unemployment, the real exchange rate and inflation and give guidance for an empirical specification.

According to theory, the natural rate of unemployment and the equilibrium real exchange rate are determined by a wide range of institutional and economic factors. Since these factors can vary over time, the NAIRU and the REER are also expected to be time varying.

The theoretical basis underpinning the unemployment relationship is the Layard, Nickell and Jackman (1991) "work horse" model for price and wage setting. The discussion below is highly simplified with respect to information and focuses only on price uncertainties.

The general idea is that real wages and employment are determined by two relationships, describing firm and union behavior. It is assumed that both product and labor markets are characterized by imperfect competition.

Firms set prices as a mark-up on wage costs. Changes in demand may have an effect because the marginal productivity of labor depends on the amount of labor used and because the profit margin might vary over the business cycle.

Wage setting is described by a relationship that can be derived from e.g. bargaining models (Layard, Nickell and Jackman, 1991; Blanchflower and Oswald, 1994; Forslund, 1995). The outcome is that wages are set as a mark-up on the value of the bargaining parties' alternative payoffs. The value of not being employed will depend on the unemployment rate, the degree of accommodation

[2] Regarding the real exchange rate, there is a voluminous empirical literature that takes as its starting point some simple accounting relationships. This literature is reviewed in MacDonald (2000). Empirical testing of the more rigorous theoretical models of the new open macroeconomics is still in its infancy. Recent surveys are Ghironi (2000) and Lane (2001).

through active labor market policies (ALMP) and the compensation when not employed, captured by the replacement ratio.

Higher unemployment indicates a higher probability of not being employed, which reduces wage pressure. ALMP can, on the one hand, increase the welfare of the unemployed and thus increase wage pressure. On the other hand, it could reduce wage pressure by increasing matching, competition and productivity (Calmfors, Forslund and Hemström, 2002). The net effect of ALMP is an empirical question. Higher compensation when not employed is expected to raise wage pressure.

Wage setters are assumed to care about after tax real consumption wages while firms are concerned about real product wages. There is a wedge between these measures of real wages that consist of a tax part including value added tax and a price part. The tax part is:

$$\theta = (1+s) + (1+\tau) - (1-t)\,,$$

where $s$ is the payroll tax rate, $\tau$ the value added tax rate and $t$ the income tax rate. The price part of the wedge is the ratio of the consumer price to the producer price. Since consumption consists of both home produced and imported goods and services, the price part of the wedge can be expressed as:

$$(1-\varpi)(c+p^{*}-p),$$

where $\varpi$ is the weight of domestic goods and services in the consumption basket, $c$ is the nominal exchange rate and $p^{*}$ is the foreign price level. Thus, the price wedge is a function of the real exchange rate $e$, where $e = c+p^{*}-p$. This is how the open economy dimension enters the model. An increase in the real exchange rate, a depreciation, increases the consumer price level and thus the demand for higher nominal wages in order to keep real consumption wages unchanged. This will raise real product wages and reduce employment.

Beside the standard model, it has been suggested that demographic variation can affect unemployment (Salemi, 1999; Barwell, 2000; Nordström Skans, 2002). Wages, unemployment and probabilities to reenter employment after being unemployed differ among different age groups. An increase in the fraction of young people in the labor force could on the one hand increase unemployment but on the other hand reduce persistence and thus long term unemployment. Likewise, an increase in the number of old workers in the labor force could reduce average unemployment but increase persistence and long term employment.

Wage setters are assumed not to have perfect foresight with regard to prices. A common assumption is that wages are set with respect to expected producer prices, $p^{e}$.

Combining price and wage setting, the considerations above can motivate a reduced log linearized unemployment relationship of the following form:

$$u = \gamma_0 - (p-p^{e}) - \gamma_1(u-u^{c}) + \gamma_2 r + \gamma_3 e + \gamma_4 \theta + \gamma_5 a + \gamma_6 old + \gamma_7 young, \tag{1}$$

where $u$ is the open unemployment rate, $u^c$ is the cyclical open unemployment rate, $r$ is the replacement ratio, $e$ is the real exchange rate, $a$ is a measure of the degree of accommodation of unemployment through active labor market policy, *old* the fraction of old people in the population (50-64 years), *young* the fraction of young people in the population (15-24 years), and superscript $e$ denotes expectations.

The open economy dimension enters the model, as indicated above, by the fact that consumers consume both domestically produced and imported goods and services. Often, especially in the simple expectations-augmented Phillips curve approach, the NAIRU is calculated in a closed economy framework. In an open economy such an assumption is not consistent with a unique natural rate (Joyce and Wren-Lewis, 1991; Layard, Nickell and Jackman, 1991; Bean, 1994).

From expression (1) above it is clear that the real exchange rate affects unemployment. The real exchange rate is driven by domestic demand and fiscal policy among other factors and cannot be treated as exogenous. Hence structural fiscal policy will influence the current account, the equilibrium real exchange rate and the NAIRU. Hence, in order to complete the model we need to specify a relationship for the exchange rate.

Lane and Milesi-Ferretti (2000) presents a model of the real exchange rate that is firmly based in the new open economy macroeconomics paradigm. They derive a real exchange rate equation in which the explanatory variables are exogenous terms of trade shocks, net foreign assets, and a Balassa-Samuelson effect. We use this as a guideline for our own specification.

The effect of a terms of trade shock on the real exchange rate is in general theoretically ambiguous (see e.g. Persson and Svensson, 1985). However, a positive terms of trade shock is usually found to lead to a significant appreciation of the real exchange rate (Lane and Milesi-Ferretti, 2000; Dungey, 2002; Nilsson, 2002).

A country's net saving relative to the net saving in the rest of the world determines its net foreign asset position. The theory cited above does not discuss what is the optimal or equilibrium net foreign asset position. We note that an important and presumably exogenous determinant of net saving is the evolution over time of the demographic composition of the population, since the savings ratio differ among cohorts. Lindh and Malmberg (1999) present evidence that the proportion of middle-aged people in the population has a positive effect on investment as well as on savings, making the effect on net savings ambiguous. The positive effect on saving reflects the fact that the middle-aged are nearing retirement. The reason for the positive effect on investment is not as obvious. Two possible explanations are given. First, the middle-aged tend to transfer wealth from real to financial assets which, given home bias in investment, would decrease the local cost of capital. Second, the group of middle-aged people is a relatively productive age group, which means lower effective capital intensity and a lower relative cost of capital.[3]

[3] Lindh and Malmberg (1999) define middle-aged as the age group 50-64 years old, while we use 45-59 years old in the empirical part of the paper. We use this definition because

The fiscal position of the government sector can also be an important determinant of net saving (to the extent that Ricardian equivalence does not hold).[4] It is not clear what effect an increase in the fiscal deficit will have on the real exchange rate. Hakkio (1996) discusses some possible channels through which the fiscal position could influence the exchange rate. On the one hand, increased borrowing by the government to finance a deficit will lead to lower national savings and higher domestic interest rates. This in turn should lead to a shift in demand from foreign assets in favor of domestic assets, which would lead to an appreciation of the exchange rate. This is the textbook example (see e.g. Ball and Mankiw (1995)). On the other hand, an increased deficit could lead to higher expected inflation, a higher foreign exchange risk premium, and a lower expected rate of return on domestic securities. This would instead imply a portfolio shift in favor of foreign assets, which should lead to a depreciation of the exchange rate. Thus, whether an increased deficit will lead to an appreciation or a depreciation is an empirical question.

The Balassa-Samuelson effect is captured by including GDP relative to foreign GDP in Lane and Milesi-Ferretti (2000). GDP is used as a crude measure of the development of productivity in the tradables sector of the economy. If the productivity development in the tradables sector is faster than in the foreign tradables sector this will lead to relatively higher wages which will spill over to the non-tradables sector where it results in relatively higher non-tradables prices. This implies an appreciation of the real exchange rate. Another argument for higher productivity to lead to an appreciation of the exchange rate is that foreign capital is attracted by the higher potential returns on investment in a faster growing economy. What really should matter in the longer run is the trend growth of output. We therefore use an unobserved components model to decompose GDP into trend and cycle. Another reason for decomposing GDP into trend and cycle in an exchange rate model is that the real interest rate should vary over the business cycle. The interest differential is often argued to be an important determinant of the real exchange rate in the short run (e.g. in MacDonald and Marsh, 1999).

Based on the discussion above we arrive at the following equation for the real exchange rate:

$$e = \alpha_0 + \alpha_1 q + \alpha_2 (d - d^*) + \alpha_3 (g - g^*) + \alpha_4 [(y - y^n) - (y^* - y^{n*})], \quad (2)$$

where $q$ is the terms of trade, $d$ is the share of middle aged people in the population, and $g$ is the structural government budget deficit as a share of GDP. Hence, all business cycle frequency movements in the exchange rate, like the ex ante real interest rate and the cyclical part of the government's budget deficit, are captured by the last term in (2). Asterisks denote foreign variables.

many of the countries in our 'rest of the world variables' have a lower retirement age than 65, especially if we want to consider the actual retirement age.

[4] A similar decomposition of net foreign assets into demographic and fiscal variables is employed in Masson, Kremers and Horne (1994).

We define equilibrium as when: $p - p^e = 0$, $y - y^n = 0$ (or $u - u^n = 0$), $y^* - y^{n*} = 0$. This means that there are no price expectations errors and that the output (and unemployment) gaps are closed. Using equations (1) and (2), as well as the equilibrium conditions, we arrive at an expression for the equilibrium unemployment rate $u^n$,

$$u^n = \gamma_0 + \gamma_2 r + \gamma_3 e + \gamma_4 \theta + \gamma_5 a + \gamma_6 old + \gamma_7 young, \tag{3}$$

and for the equilibrium real exchange rate $e^n$,[5]

$$e^n = \alpha_0 + \alpha_1 q + \alpha_2 (d - d^*) + \alpha_3 (g - g^*) . \tag{4}$$

Using the Okun relationship

$$(y - y^n) = -\mu (u - u^n) , \tag{5}$$

where the parameter $\mu$ is expected to be positive, the cyclical part of the exchange rate, $e^c$, can be expressed as

$$e^c = e - e^n = -\alpha_4 [\mu (u - u^n) + (y^* - y^{n*})] . \tag{6}$$

Using equations (1), (3) and (4) and solving for the price expectation error, we get

$$p - p^e = - (\mu \delta_1 + \gamma_1) (u - u^n) + \gamma_3 (e - e^n) . \tag{7}$$

Sweden has during the last decade and is at present enjoying a credible inflation targeting monetary policy regime. Thus, it would be reasonable to assume that the rate of inflation is stationary. However, looking at our sample, a unit root in the rate of inflation is not rejected, c.f Table 1, and we have chosen to treat inflation as non stationary. Assuming that the rate of inflation follows a unit root process and using equation (6), (7) can be rewritten as

$$\Delta^2 p = \lambda_1 u^c + \lambda_2 (y^* - y^{n*}), \tag{8}$$

where $u^c = u - u^n$ is cyclical unemployment and $\Delta^s$ is the $s^{th}$ difference operator. Thus the change in the rate of inflation will depend on the domestic and foreign unemployment/output gaps.

# 3 The empirical model

We divide both unemployment and the real exchange rate into two unobserved components, one equilibrium rate which could be non-stationary and a stationary cyclical component,

$$u_t = u_t^n + u_t^c + \varepsilon_{u,t}^n \tag{9}$$

[5] The equilibrium concept used here is that of a medium-term "equilibrium" and should not be confused with the steady state solution. The rationale for talking about an equilibrium in the medium term is that the explanatory variables we are considering move slowly over time relative to the sample size we, and most other REER studies, are considering. Because of the relatively short sample the variables will usually be found to be non-stationary and will have to be treated as such in the formal analysis.

and

$$e_t = e_t^n + e_t^c + \varepsilon_{e,t}^n, \tag{10}$$

where $u^n$, $e^n$ and $e^c$ are given by equations (3), (4), and (6)

The cyclical component of unemployment, $u^c$, is modelled as a stationary AR-process

$$u_t^c = \phi_1 u_{t-1}^c + \phi_2 u_{t-2}^c + \varepsilon_{u,t}^c. \tag{11}$$

Stationarity implies that the roots of the polynomial equation

$$1 - \phi_1 L - \phi_2 L^2 = 0,$$

where $L$ is the lag operator, should lie outside the unit circle. The assumption of an AR(2) process is not crucial, but it fits the data.

Note that we so far only have three shocks, a NAIRU shock, an REER shock and a common cyclical shock.

### 3.1 Identification

The UC-model given in the previous section is generally not identified. To achieve an identified model we follow Lindblad (1997) and Salemi (1999).

First, identification requires a variable that is related to either the cyclical or the permanent component of unemployment (or the real exchange rate), but not to both. The expectation augmented Phillips curve given by equation (8) meets this requirement and is modeled as

$$\Delta\Delta_4 p_t = \lambda_1(L) u_t^c + \lambda_2(L) y_t^{c*} + \varepsilon_t^p, \tag{12}$$

see discussion below.

The second assumption is that all four shocks $\varepsilon_{j,t}^i$ are mutually uncorrelated and normally distributed with variances $\sigma_j^{2,i}$, $i = n, c$ and $j = u, e, p$.

In our model we are not able to identify separate means for unemployment and the NAIRU or for the real exchange rate and the REER. Salemi (1999), who has the same problem, suggests that the problem can be circumvented by de-meaning all variables. We follow this route, however noting that we are subtracting sample means from non-stationary variables does not make the variable at hand stationary. Our purpose is only to handle the identification problem. Thus the third assumption is that the sample means of $u^n$ and $e^n$ are the same as the sample means of $u$ and $e$, i.e. we assume that the sample means of the cyclical components of unemployment and the real exchange rate are both zero. The restriction that the sample means of the cyclical components are zero is reasonable, especially if the sample is long. These restrictions are imposed by defining all explanatory variables in equations (3), (4) and (8) as deviations from sample means and excluding constants from the unemployment, real exchange rate and Phillips curve equations. This third restriction unfortunately reduces our possibility to make more precise statements on the levels of NAIRU, REER, and the cyclical position. However, the dynamics are not affected.

## 3.2 The Phillips curve

Since the Phillips curve is used for identification, it is important that the specification is chosen carefully so that no bias is introduced into the parameter estimates for the rest of the model. Ignoring supply side changes will in general give rise to misspecification problems. In order to handle this, we have chosen to use the change in the annual rate of import price changes, $\Delta\Delta_4 p_M$, and the change in the annual rate of labor productivity growth, $\Delta\Delta_4 pr$, as proxies for supply shocks. Thus the extracted NAIRU and REER are the unemployment and real exchange rate levels which are consistent with stable inflation in absence of supply shocks. Thereafter we tested several different specifications of our Phillips curve, mainly varying the number of lags of the exogenous variables. The selected specification is parsimoniously specified and the point estimates of the parameters seem reasonable.

We have modeled an MA(4) error term for the Phillips curve:

$$\varepsilon_{p,t} = \rho\varepsilon_{p,t-4} + \xi_{p,t},$$

where $\xi_{p,t}$ is an i.i.d. error term. The reason for this is that in the estimations we use $\Delta\Delta_4$ rather than $\Delta^2$ in order to handle the seasonality in the inflation series. Serial correlation will result because of this way of constructing the variables and implies that the residual follows an MA(4) process.

## 3.3 The state space form

In order to estimate the model, we put it in state space form. The transition equations are given by

$$U_t = \Phi U_{t-1} + \varepsilon_t,$$

where

$$U_t = \begin{pmatrix} u_t^c \\ u_{t-1}^c \\ \varepsilon_{p,t} \\ \varepsilon_{p,t-1} \\ \varepsilon_{p,t-2} \\ \varepsilon_{p,t-3} \end{pmatrix}, \Phi = \begin{pmatrix} \phi_1 & \phi_2 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \rho \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \end{pmatrix}, \varepsilon_t = \begin{pmatrix} \varepsilon_{u,t}^c \\ 0 \\ \xi_{p,t} \\ 0 \\ 0 \\ 0 \end{pmatrix}.$$

The measurement equations are given by

$$Y_t = \Lambda U_t + \Psi X_t + \nu_t,$$

where

$$Y_t = \begin{pmatrix} u_t \\ \Delta e_t \\ \Delta\Delta_4 p_t \end{pmatrix}, \Lambda = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ \lambda_{10} & \lambda_{11} & 0 & 0 & 0 & 0 \\ \lambda_{20} & \lambda_{21} & 1 & 0 & 0 & 0 \end{pmatrix}, \nu_t = \begin{pmatrix} \varepsilon_{u,t}^n \\ \varepsilon_{e,t}^n \\ 0 \end{pmatrix}$$

and $X_t$ is a vector of exogenous or predetermined variables.

Our theoretical discussion suggests what variables to be included in our empirical model, but it does not tell us much with respect to dynamics. Thus, in the empirical analysis we have chosen a specification that is flexible in order to capture lagged effects and to fulfill different statistical criteria. Using a general-to-specific specification approach, the exact specification of the measurement equations that we end up estimating is the following:

$$u_t = u_t^c + \beta_1 a_t + \beta_2 a_{t-1} + \beta_3 r_t + \beta_4 r_{t-1} + \beta_5 \theta_t + \beta_6 \theta_{t-1} + \beta_7 \theta_{t-3} + \beta_8 e_{t-1} + \beta_9 old_{t-1} + \beta_{10} young_{t-1} + \varepsilon_{u,t}^n \quad (13)$$

$$\Delta e_t = \lambda_{10} u_t^c + \beta_{11} e_{t-1} + \beta_{12} (d - d^*)_{t-1} + \beta_{13} q_{t-1} + \beta_{14} g_{t-1} + \beta_{15} g_{t-1}^* + \beta_{16} \Delta (d - d^*)_t + \beta_{17} \Delta q_t + \beta_{18} \Delta g_t + \beta_{19} \Delta g_t^* + \beta_{20} (y^* - y^{n*})_t + \varepsilon_{e,t}^n \quad (14)$$

$$\Delta\Delta_4 p_t = \lambda_{20} u_t^c + \lambda_{21} u_{t-1}^c + \beta_{21} y_t^{c*} + \beta_{22} \Delta\Delta_4 p_{m,t} + \beta_{23} \Delta\Delta_4 p_{m,t-3} + \beta_{24} \Delta\Delta_4 pr_{t-2} + \beta_{25} \Delta\Delta_4 pr_{t-3} + \varepsilon_{p,t} \quad (15)$$

This yields a total of 35 coefficients to be estimated: $\phi_1$, $\phi_2$, $\lambda_{10}$, $\lambda_{20}$, $\lambda_{21}$, $\beta_1$, $\beta_2$, ..., $\beta_{25}, \rho$, $\sigma_u^n$, $\sigma_u^c$, $\sigma_e$, and $\sigma_p$. The relative budget deficit variable was not significant and we then decided to relax the restriction of equal coefficients on the domestic and foreign deficits. A long-run exchange rate relationship can be formed using the coefficients $\beta_{11}$, $\beta_{12}$, ..., $\beta_{15}$. We derive such a relationship explicitly in the next section for the estimated model.

The coefficients in the model were estimated by Maximum Likelihood. The prediction error decomposition form of the likelihood was used. The mean and covariance matrix of the conditional distribution are given by the Kalman filter.[6] The specification in (13) may need some comment. As one might suspect and as we will show in the next section all variables in (13), with the exception of the unemployment gap $u_t^c$, are nonstationary. However, as we will see in the next section the error term, $\varepsilon_{u,t}^n$, is actually well behaved. This is the result of having employed a general-to-specific modelling approach and standard inference can thus be used (see Phillips and Hansen (1990) for the asymptotic results and Hendry and Juselius (1999) for some small sample results).

# 4 Empirical results

The empirical analysis uses Swedish quarterly data ranging from 1972:1 to 2001:4 (after having allowed for lags). The data is described in an appendix

[6] The BFGS algorithm in RATS for Windows 4.31 was used. We also used the Marquart algorithm in Eviews as a robustness check. The point estimates were approximately the same. In preliminary work we used the SIMPLEX algorithm in RATS. However, this algorithm did not do a good job of maximizing the likelihood. Repeated restarting of the maximization from a converged state yielded additional improvement in the likelihood value, even though the convergence criterion had not been changed.

and some series are shown in Figures 1-13 along with X11 seasonally adjusted series when appropriate. The results from estimating the full model above are given equation by equation in the tables below. In Model 1 the exchange rate is the TCW real effective exchange rate, while in Model 2 we look at the SEK/EUR real exchange rate. Models 3 and 4 are subperiod estimates of Model 1 for the periods 1972-1992 and 1982-2001 respectively, with approximately 80 observations in each subsample.[7] Before we look at the estimated models we briefly consider the question of stationarity of the variables involved in the analysis.

Identification of the stationary cyclical component requires that all variables in the expectation augmented Phillips-curve are stationary. In addition all variables describing the natural rate of unemployment and the equilibrium real exchange rate must be integrated of the same order. However, the first-differenced variables in the exchange rate equation should of course be stationary. Table 1 presents the results from the standard augmented Dickey-Fuller test. The lag length is determined by the Akaike information criteria. We interpret the results to be that all variables are integrated of the expected order. However, in the case of the accommodation rate and the replacement ratio the hypothesis of a unit root is marginally rejected (at the 10 % level). Nevertheless, we choose to treat these variables as non-stationary in the following analysis.[8]

When estimating the models 1 and 2 we started out with a general specification and then reduced the model with respect to if the variable was significant or not and if the models behaved well in a statistical manner. The point estimates of the AR(2) parameters and thus the cyclical part of open unemployment fulfill the requirements for stationarity. An assumption is that the Swedish economy acts as if it is open. The open economy model assumption can be examined by testing the hypothesis that the exchange rate parameter is zero in the unemployment equation reported in Table 2. It is clear that this is not the case and we can reject the hypothesis of a closed economy framework. The natural rate is, as expected, increasing in a depreciation of the real exchange rate. An increase of labor market programmes tends to reduce the natural rate of open unemployment, which is in line with a quite usual result that an increase in programme participation reduces *open* unemployment (Calmfors et al., 2002). The replacement ratio has the expected positive sign, but is imprecisely estimated. This could be due to the treatment of the replacement ratio as exogenous. Forslund and Kolm (2000) find that the replacement ratio could be related to the accommodation rate. A higher tax wedge leads to an increase in the NAIRU, as expected. The shares of young and old people in the labor force respectively have the expected positive sign, although the estimated coefficients are not significantly different from zero at the usual significance levels. The estimated

[7] Using a subsample for the floating exchange rate period 1993-2001 would have yielded too few observations for the exercise to be meaningful. Even the 80 observations now used for each subsample represents a very small sample size, considering the number of parameters estimated, and the results should therefore be interpreted with caution.

[8] The rate of unemployment is bounded by definition. However, using our sample we could not reject that the rate of unemployment is non-stationary. Forslund (1995) tests several different samples and generally gets the same result.

Table 1: Unit root tests

***, **, * denote significance at the 1, 5, and 10 percent level respectively, using Mac Kinnon critical values for rejection of the hypothesis of a unit root. Two sets of statistics are reported for foreign variables: Model 1 (TCW)/Model 2 (SEK/EUR).

| **Variable** | **Test statistic** | **Lags** |
|---|---|---|
| $u$ | -1.36 | 1 |
| $e$ | -1.68/-1.97 | 1/1 |
| $\Delta e$ | -7.28***/-7.18*** | 1/1 |
| $\Delta_4 p$ | -0.24 | 4 |
| $\Delta\Delta_4 p$ | -5.74*** | 2 |
| $a$ | -2.83* | 1 |
| $r$ | -2.88* | 1 |
| $\theta$ | -2.15 | 4 |
| $old$ | -1.81 | 5 |
| $young$ | -2.14 | 5 |
| $d - d^*$ | -1.50/-1.63 | 6/5 |
| $\Delta(d - d^*)$ | -3.12**/-2.55 | 5/5 |
| $q$ | -2.04 | 1 |
| $\Delta q$ | -7.50*** | 1 |
| $g$ | -2.08 | 3 |
| $\Delta g$ | -3.42** | 3 |
| $g^*$ | -1.58/-1.38 | 2/4 |
| $\Delta g^*$ | -5.11***/-4.73*** | 1/4 |
| $y^* - y^{n*}$ | -5.24***/-5.32*** | 4/4 |
| $\Delta\Delta_4 p_M$ | -8.98*** | 3 |
| $\Delta\Delta_4 pr$ | -8.46*** | 4 |

variance of the cyclical shock is larger than that of the natural rate shocks. This is in line with the results in Lindblad (1997) but contrary to the results in Apel and Jansson (1999).

Models 3 and 4 suggest that the estimates in the unemployment equation could be unstable across the subperiods. Model 3 especially does not look to be well specified. This evidence of instability is not surprising considering the small sample size and the evolution of the open unemployment series depicted in Figure 1. However, we note that the negative effect of labor market programs on open unemployment nevertheless is stable across the subperiods.

Figure 14 shows the actual, natural and cyclical rate of unemployment. The levels of the NAIRU and the cyclical component should be interpreted with great caution due to the identifying restriction that the sample mean of the actual rate of unemployment and the NAIRU are the same. The results suggest that the NAIRU increased by 1-1.5 percentage points during 1980-85 and has since then remained more or less stable. Thus, during the last decade the NAIRU has increased little, which implies that the dramatic changes in the Swedish unemployment rates during the 1990s mainly was a cyclical phenomenon.

We did some further analysis of what is driving the NAIRU in model 1. We found that the tax wedge has contributed to an increase of the NAIRU during the period 1972-1990 of almost a full percentage point. During 1990-1991 the tax wedge then resulted in a 0.5 percentage points reduction of the NAIRU, coinciding with the big tax reforms of 1990 and 1991, which was designed to bring down rates and broaden the tax base. After 1991 the tax wedge has had a negligible effect. The share of old workers has had a dampening effect during the 1980s. But during the 1990s this age group has contributed to an increase in the NAIRU. The share of young workers grew quite rapidly in the early part of the sample and contributed to increase NAIRU during that period. The weakening of the real exchange rate since 1972 has resulted in an increase of the NAIRU of around 0.6 percentage points. An increasing accommodation ratio tended to reduce the NAIRU during the 1970s, followed by a sharp increase in 1980-81. In the 1990s the accommodation ratio has contributed to making the NAIRU more volatile. The replacement ratio has contributed to a decrease in the NAIRU since 1994.

In Table 3 we present the estimated real exchange rate equation (14). The first difference of all non-stationary variables are included as explanatory variables to capture the short-run dynamics along with the domestic unemployment gap and the foreign output gap.

The unemployment gap coefficient $\lambda_{10}$ is highly significant. The error correction implicit in Table 3 for Models 1 and 2 are

$$-0.186\left[e_{t-1}-\left(0.16(d-d^*)_{t-1}-0.86q_{t-1}+0.009g_{t-1}-0.075g^*_{t-1}\right)\right],$$

$$-0.198\left[e_{t-1}-\left(0.11(d-d^*)_{t-1}-0.56q_{t-1}+0.006g_{t-1}-0.045g^*_{t-1}\right)\right]$$

The speed of the error correction is about the same for the two exchange rates, with a half-life of 3-4 quarters. The long-run elasticities are generally higher for the TCW compared to the SEK/EUR.

Table 2: Unemployment equation

Dependent variable: open unemployment, percent of total labor force. White standard errors are reported within parentheses below the estimated coefficients. Serial corr. is a Box-Ljung Q(k) test against serial correlation based on k=11 autocorrelations. Cross corr. is a Q(k) test of the correlation of residuals across equations with k = 5 lags/5 leads. Heterosk. is Engle's LM test against first order autoregressive conditional heteroskedasticity (Chi-squared with 1 d.f.). $R_d^2$ is the coefficient of determination suggested for non-stationary time series by Harvey (1989). A positive $R_d^2$ implies a better fit than a random walk.

| **Variable** | **Model 1** | **Model 2** | **Model 3** | **Model 4** |
|---|---|---|---|---|
| $\phi_1$ | 1.83 (0.04) | 1.83 (0.02) | 1.94 (0.10) | 1.83 (0.10) |
| $\phi_2$ | −0.85 (0.04) | −0.84 (0.02) | −0.99 (0.10) | −0.85 (0.10) |
| $a_t$ | −1.82 (0.27) | −1.81 (0.25) | −1.56 (0.19) | −1.71 (0.30) |
| $a_{t-1}$ | −0.50 (0.33) | −0.48 (0.37) | 0.05 (0.19) | −0.60 (0.42) |
| $r_t$ | 0.04 (0.14) | 0.09 (0.13) | −0.16 (0.15) | 0.45 (0.42) |
| $r_{t-1}$ | 0.23 (0.25) | 0.25 (0.26) | −0.12 (0.15) | 1.28 (0.49) |
| $\theta_t$ | 0.68 (0.30) | 0.64 (0.38) | −0.43 (0.39) | 0.96 (0.91) |
| $\theta_{t-1}$ | 0.51 (0.41) | 0.41 (0.45) | −0.37 (0.43) | −0.14 (1.02) |
| $\theta_{t-3}$ | 0.84 (0.33) | 0.77 (0.44) | −0.13 (0.34) | 0.18 (1.04) |
| $e_{t-1}$ | 1.81 (0.70) | 1.55 (0.71) | −0.18 (0.48) | 2.31 (1.17) |
| $old_{t-1}$ | 1.55 (2.81) | 1.71 (2.76) | 2.03 (3.05) | −0.40 (3.48) |
| $young_{t-1}$ | 0.97 (2.85) | 1.29 (2.78) | 1.30 (2.77) | −10.72 (5.74) |
| $\sigma_u^c$ | 0.13 (0.02) | 0.13 (0.02) | 0.08 (0.02) | 0.16 (0.03) |
| $\sigma_u^n$ | 0.08 (0.02) | 0.08 (0.02) | 0.04 (0.01) | 0.09 (0.02) |
| $R^2$ | 0.99 | 0.99 | 0.98 | 0.99 |
| $R_d^2$ | 0.57 | 0.57 | 0.72 | 0.58 |
| Serial corr. (p-value) | 0.630 | 0.576 | 0.501 | 0.466 |
| Cross corr. $\varepsilon_e^n$ (p-value) | 0.538/0.739 | 0.751/0.654 | 0.106/0.014 | 0.325/0.361 |
| Cross corr. $\varepsilon_p$ (p-value) | 0.515/0.488 | 0.566/0.536 | 0.051/0.053 | 0.946/0.689 |
| Heterosk. (p-value) | 0.005 | 0.001 | 0.597 | 0.326 |
| Exchange rate | TCW | SEK/EUR | TCW | TCW |
| Sample | 1972-2001 | 1972-2001 | 1972-1992 | 1982-2001 |

Table 3: Exchange rate equation

Dependent variable: the percentage change in the real exchange rate. White standard errors are reported within parentheses below the estimated coefficients. Serial cor. is a Box-Ljung Q(k) test against serial correlation based on k=11 autocorrelations. Cross corr. is a Q(k) test of the correlation of residuals across equations with k = 5 lags/5 leads. Heterosk. is Engle's LM test against first order autoregressive conditional heteroskedasticity (Chi-squared with 1 d.f.).

| **Variable** | **Model 1** | **Model 2** | **Model 3** | **Model 4** |
|---|---|---|---|---|
| $u_t^c$ | $4.7 \cdot 10^{-3}$ <br> $(1.6 \cdot 10^{-3})$ | $3.6 \cdot 10^{-3}$ <br> $(2.2 \cdot 10^{-3})$ | $3.7 \cdot 10^{-3}$ <br> $(4.0 \cdot 10^{-3})$ | $6.1 \cdot 10^{-3}$ <br> $(2.8 \cdot 10^{-3})$ |
| $e_{t-1}$ | $-0.186$ <br> (0.048) | $-0.198$ <br> (0.055) | $-0.238$ <br> (0.065) | $-0.217$ <br> (0.057) |
| $(d-d^*)_{t-1}$ | 0.030 <br> (0.010) | 0.021 <br> (0.006) | 0.027 <br> (0.008) | 0.082 <br> (0.029) |
| $q_{t-1}$ | $-0.160$ <br> (0.058) | $-0.111$ <br> (0.067) | $-0.203$ <br> (0.064) | $-0.152$ <br> (0.074) |
| $g_{t-1}$ | $1.6 \cdot 10^{-3}$ <br> $(1.5 \cdot 10^{-3})$ | $1.2 \cdot 10^{-3}$ <br> $(1.7 \cdot 10^{-3})$ | $-1.2 \cdot 10^{-4}$ <br> $(1.6 \cdot 10^{-3})$ | $2.4 \cdot 10^{-3}$ <br> $(1.6 \cdot 10^{-3})$ |
| $g_{t-1}^*$ | $-0.014$ <br> (0.004) | $-0.009$ <br> (0.003) | $-0.012$ <br> (0.004) | $-0.023$ <br> (0.005) |
| $\Delta(d-d^*)_t$ | 0.014 <br> (0.040) | 0.033 <br> (0.048) | 0.004 <br> (0.047) | 0.100 <br> (0.071) |
| $\Delta q_t$ | $-0.601$ <br> (0.204) | $-0.437$ <br> (0.141) | $-0.577$ <br> (0.146) | $-0.608$ <br> (0.208) |
| $\Delta g_t$ | $-2.9 \cdot 10^{-4}$ <br> $(3.7 \cdot 10^{-3})$ | $1.0 \cdot 10^{-3}$ <br> $(4.2 \cdot 10^{-3})$ | $-9.5 \cdot 10^{-3}$ <br> $(5.0 \cdot 10^{-3})$ | $2.1 \cdot 10^{-3}$ <br> $(3.8 \cdot 10^{-3})$ |
| $\Delta g_t^*$ | $-3.2 \cdot 10^{-3}$ <br> $(6.4 \cdot 10^{-3})$ | $-2.4 \cdot 10^{-3}$ <br> $(6.9 \cdot 10^{-3})$ | $5.9 \cdot 10^{-4}$ <br> $(7.9 \cdot 10^{-3})$ | $-1.6 \cdot 10^{-3}$ <br> $(11.3 \cdot 10^{-3})$ |
| $(y^* - y^{n*})_t$ | $-5.3 \cdot 10^{-3}$ <br> $(1.6 \cdot 10^{-3})$ | $-6.3 \cdot 10^{-3}$ <br> $(2.2 \cdot 10^{-3})$ | $-2.1 \cdot 10^{-3}$ <br> $(2.3 \cdot 10^{-3})$ | $-15.3 \cdot 10^{-3}$ <br> $(4.6 \cdot 10^{-3})$ |
| $\sigma_e$ | 0.022 <br> (0.002) | 0.024 <br> (0.001) | 0.019 <br> (0.002) | 0.022 <br> (0.002) |
| $R^2$ | 0.34 | 0.27 | 0.39 | 0.53 |
| Serial corr. (p-value) | 0.439 | 0.091 | 0.005 | 0.169 |
| Cross corr. $\varepsilon_u^n$ (p-value) | 0.739/0.539 | 0.654/0.751 | 0.014/0.106 | 0.361/0.325 |
| Cross corr. $\varepsilon_p$ (p-value) | 0.177/0.486 | 0.562/0.779 | 0.105/0.160 | 0.056/0.140 |
| Heterosk. (p-value) | 0.951 | 0.775 | 0.876 | 0.833 |
| Exchange rate | SEK/TCW | SEK/EUR | SEK/TCW | SEK/TCW |
| Sample | 1972-2001 | 1972-2001 | 1972-1992 | 1982-2001 |

The long-run relationships are shown together with the actual real effective exchange rates in Figure 15 and 21 respectively. Both follow a depreciating trend over the whole sample period 1972-2001. The nominal exchange rate was fixed (but devalued several times) up until November 19, 1992, when the Krona was allowed to float. In contrast to the NAIRU and cyclical unemployment, the transitory component of the exchange rate includes the foreign output gap and the first differences of the long-run exogenous variables in addition to the domestic unemployment gap. According to the model the real exchange rate has been undervalued during most of the floating rate period, since 1993.

When analyzing how different factors in model 1 have influenced the REER, we find that the demographic variable contributed to appreciating the exchange rate in the 1970s, which was a period when the group of middle-aged savers was declining relative to the TCW area. However, during the 1980s this group was increasing and contributed to a weakening of the exchange rate but this trend was reversed again in the 1990s. During the early 1970s the terms of trade had a depreciating effect followed by a sharp appreciating effect in 1986. In recent years the terms of trade have again deteriorated. The Swedish structural budget deficit had its most noticeable effect on the real exchange rate during the crisis years of the early 1990s. During the deep recession of 1991-93 the budget went from a surplus of 2 percent to a deficit of 7 percent. This also contributed to a depreciation of the exchange rate. According to our model the reduction of the foreign budget deficit has had a strongly depreciating effect on the real exchange rate during the floating exchange rate period since 1992, although the trend is broken in 2000. Even though it is natural, given our point estimates, to expect an appreciation of the TCW or Euro when the budget stance in these currency areas improves, we had not expected to find such a strong effect of the foreign deficit on the REER. A closer look at the time series of the foreign structural deficit led us to suspect a spurious regression result. However, looking at Model 3 for the shorter period 1972-1992, excluding the foreign budget consolidation during the 1990's, still results in a highly significant (but smaller) estimated coefficient. In Model 4 (1982-2001) the coefficient is twice as high in absolute terms and even more significant. Thus the results suggest that the strong appreciation of the TCW and the Euro against the Swedish Krona during the 1990's was primarily driven by the improved foreign fiscal position. The improvement in the Swedish fiscal balance was of course even greater during the same period. The statistically insignificant effect of the Swedish structural deficit could be due to collinearity problems.

In Figure 16 and 22 we show the complete model that allows for short run dynamics as well as both domestic and foreign cyclical movements. We call this model the fundamental exchange rate. The fundamental model seems to do a good job of tracking the movements in the actual exchange rate, except for the mid-1980's. The results are promising, especially keeping in mind that the sample period spans no less than five devaluations under the fixed exchange rate regime and a regime shift to a free float. We also estimated a version of Model 1 with an exchange rate regime-shift variable. We did this by specifying the coefficient on the lagged exchange rate as $\beta_{11} = b_0 + b_1 D_t$, where $D_t =$

1 during the floating rate period and $D_t = 0$ during the fixed rate period. In this model we can test whether the error correction is faster during the floating rate period ($|b_0 + b_1| > |b_0|$). This proves to be the case, with a half-life of less than a year compared to a half-life of four years during the fixed-rate period, when corrections through devaluations are excluded by using dummy variables to account for the spikes in the series caused by the devaluations. If we instead include the devaluations, i.e. do not use devaluation dummies, there is no significant difference between the error correction coefficient in the floating versus fixed-rate periods. Hence, during the fixed-rate period adjustments to the real exchange rate also mainly took place through changes in the nominal exchange rate (devaluations) and not through changes in the relative price level.

Figure 17 decomposes the estimated model into a cyclical component, the first-differenced variables, and the error correction in each period. We note that the cyclical component has exerted a depreciating effect on the exchange rate during most of the 1990's. This is also evident in Figure 18 where we have excluded the cyclical component of the exchange rate. Comparing this figure with Figure 16, it is evident that some of the overshooting after the floating of the krona in late 1992 can actually be explained by the cyclical position of the Swedish economy relative to its main trading partners.

The Phillips curve is naturally of special interest for stabilization policy. All parameters in the Phillips curve equation have the expected signs and are significant and surprisingly stable. The size of the different parameters seem reasonable. An increase in the unemployment gap by 1 percentage point in Model 1 will reduce the rate of inflation by about 0.6 percentage points four quarters later.[9] The Okun coefficient $\mu$ is often estimated to be in the range 1.5-2. Given this, our estimates suggest that an increase in the output gap by 1 percentage point will increase inflation a year later by about 0.3-0.4 percentage points. This is much in line with the results in Apel and Jansson (1999) as well as with different rules of thumb. The sum of the import price shocks are reasonable, and not far from the import penetration in private consumption according to Statistics Sweden. Regarding productivity, our point estimates indicate a limited pass-through in the short run as expected.

The finding of a significant effect from the lagged unemployment gap suggests that there may be a limit to the speed with which the gap can be closed without causing a change in inflation. This can be illustrated by rewriting the Phillips curve (dropping the import price and productivity shocks) as:

$$\Delta\Delta_4 p_t = (\lambda_{20} + \lambda_{21})\, u_t^c - \lambda_{21} \Delta u_t^c$$

or using the point estimates from Model 1,

$$\Delta\Delta_4 p_t = -0.021 u_t^c - 0.51 \Delta u_t^c. \tag{16}$$

Thus, it is clear that the *change* in the unemployment gap may be of importance for the inflation dynamics. The speed-limit can be calculated by setting

[9] See equation (16) where the point estimates are included. A shift in cyclical unemployment lasting a year gives an effect on inflation that can be calculated as $0.51 + 4 * 0.02 \approx 0.6$.

Table 4: The expectations-augmented Phillips curve

Dependent variable: the quarterly change in the annual rate of inflation. White standard errors are reported within parentheses below the estimated coefficients. Serial corr. is a Box-Ljung Q(k) test against serial correlation based on k=11 autocorrelations. Cross corr. is a Q(k) test of the correlation of residuals across equations with K = 5 lags/5 leads. Heterosk. is Engle's LM test against first order autoregressive conditional heteroskedasticity (Chi-squared with 1 d.f.).

| **Variable** | **Model 1** | **Model 2** | **Model 3** | **Model 4** |
|---|---|---|---|---|
| $u_t^c$ | $-0.531$ (0.118) | $-0.609$ (0.124) | $-0.610$ (0.067) | $-0.455$ (0.057) |
| $u_{t-1}^c$ | 0.510 (0.112) | 0.586 (0.122) | 0.364 (0.060) | 0.462 (0.053) |
| $y_t^{c*}$ | 0.060 (0.036) | 0.045 (0.037) | 0.058 (0.041) | 0.151 (0.095) |
| $\Delta^2 p_{m,t}$ | 0.062 (0.018) | 0.065 (0.017) | 0.060 (0.020) | 0.064 (0.017) |
| $\Delta^2 p_{m,t-3}$ | 0.056 (0.016) | 0.056 (0.017) | 0.057 (0.017) | 0.066 (0.015) |
| $\Delta^2 pr_{t-2}$ | $-0.100$ (0.030) | $-0.100$ (0.026) | $-0.106$ (0.031) | $-0.107$ (0.056) |
| $\Delta^2 pr_{t-3}$ | $-0.086$ (0.034) | $-0.086$ (0.025) | $-0.098$ (0.032) | $-0.062$ (0.045) |
| $\sigma_p$ | 0.527 (0.044) | 0.527 (0.045) | 0.546 (0.046) | 0.460 (0.057) |
| $\rho$ | $-0.554$ (0.081) | $-0.555$ (0.077) | $-0.616$ (0.095) | $-0.301$ (0.114) |
| $R^2$ | 0.56 | 0.56 | 0.64 | 0.57 |
| Serial corr. (p-value) | 0.612 | 0.614 | 0.214 | 0.145 |
| Cross corr. $\varepsilon_u^n$ (p-value) | 0.488/0.515 | 0.536/0.566 | 0.053/0.051 | 0.689/0.946 |
| Cross corr. $\varepsilon_e^n$ (p-value) | 0.486/0.177 | 0.779/0.566 | 0.160/0.105 | 0.140/0.056 |
| Heterosk. (p-value) | 0.998 | 0.812 | 0.765 | 0.812 |
| Exchange rate | TCW | SEK/EUR | TCW | TCW |
| Sample | 1972-2001 | 1972-2001 | 1972-1992 | 1982-2001 |

$\Delta\Delta_4 p_t = 0$ and solving for $\Delta u_t^c$, which gives

$$\Delta u_t^c = -0.04 u_t^c.$$

An implication of a speed-limit is that inflation can be stable in situations when the unemployment gap is not closed but moving towards equilibrium.

Finally, analyzing standardized residuals and autocorrelations for the residuals from the three estimated equations do not indicate that there are any major problems that we have not already dealt with.

# 5 Conclusions and summary

The Swedish unemployment rate rose rapidly during the early 1990s, but since 1997 it has fallen substantially. The central question put forward in the introduction of this paper was to what degree the dramatic changes in the Swedish unemployment rate during the 1990s reflect changes in the natural rate/NAIRU and in the business cycle.

In order to try to answer this question we estimate an open economy version of the Layard, Nickell and Jackman model for price and wage setting in an unobserved components framework.

Instead of modelling the NAIRU as a stochastic trend in a closed economy framework, which is the most common approach, we have modeled it as a function of theoretically motivated variables: taxes, active labor market policies, replacement ratio, demographic factors and, since we are modelling an open economy, the real exchange rate. All variables except the real exchange rate are treated as exogenous. Since the real exchange rate is not exogenous it has to be modeled and estimated.

In this paper we have simultaneously estimated equilibrium and cyclical movements in the rate of unemployment and in the real exchange rate. In order to identify the model we also estimated an expectations augmented Phillips curve.

Our results show that the Swedish economy acts as if it is open. The closed economy version, nested in the open economy model, is safely rejected. The development of the Swedish unemployment rate is successfully explained. The NAIRU is as expected increasing in a depreciation of the exchange rate, in the replacement ratio and in higher taxes. An increase in labor market programs tends to reduce the NAIRU, which also is expected. According to our point estimates, the NAIRU increased by approximately 1-1.5 percentage point during 1980-1985. Thereafter it has however remained quite stable. This finding implies that the dramatic unemployment changes in the 1990s mainly is a cyclical phenomenon.

The real exchange rate is successfully modeled using the terms of trade, the evolution of demographics relative to the rest of the world, and the domestic and foreign structural budget deficits. Most econometric studies of the REER use the terms of trade and some measure of net foreign assets as explanatory variables. However, net foreign assets are notoriously difficult to measure. This has led us to instead consider the most important determinants of net foreign assets, demographic variables and structural budget deficits, as explanatory variables. Our focus on the special age group that saves a relatively large share of their income relative to the corresponding foreign group and the use of structural deficits in the exchange rate equation is a novelty. The parameters have the expected signs, and the exchange rate is depreciating in the fraction of the population aged 45-59 years and in the domestic structural budget deficit. The exchange rate is strengthened in the terms of trade, the foreign structural budget deficit and the foreign output gap. Regarding the strong appreciating effect from the foreign structural deficit, we believe that it should be thought of as depreciating the foreign currency rather than fundamentally strengthening the Swedish Krona. Our exchange rate model explains a surprisingly large fraction of the variation in the real exchange rate. The results are promising, especially keeping in mind that the sample period spans no less than five devaluations and a shift from fixed to float of the nominal exchange rate, events that we do not control for. We also find that the real exchange rate does not revert faster to the REER during the floating-rate period, unless we control for the devaluations. Thus it seems as adjustments to the real exchange rate during the fixed-rate period also mainly took place through changes in the nominal exchange rate (devaluations) and not through changes in the relative price level.

The Phillips curve seems to be "alive and well". Changes in the rate of inflation are well explained by the unemployment gap and shocks to import prices and productivity. Our results also indicate that there might be a limit to the speed with which the gap can be closed without causing a change in inflation.

The open economy model presented in this paper could serve as a useful framework for thinking about equilibrium exchange rates and conversion rates for countries in the process of joining ERM2. In this kind of policy analysis it can be of interest to take into account the cyclical position of the economy relative to that of the main trading partners. This is possible to do in our model. Of course the model concept in this paper can also be used for analyzing other relationships of importance, e.g. sources of potential growth.

## 6 Data appendix

- $a = \ln(ALMP/(ALMP + OU)$ is the accommodation rate.
- $ALMP =$ The sum of all different active labor market programs that have existed during the period 1972-2000.
- $d =$ Net savers ratio, computed as the sum of 45-59 years old relative to the total population.
- $d^* =$ TCW (or EMU) weighted net savers ratio.
- $e = \ln(TCW \cdot P^*/P)$ or $e = \ln(SEK/EUR \cdot P^*/P)$ is the real exchange rate for Model 1 and 2 respectively (the real TCW index is set equal to 100 at 18 November 1992, while the real SEK/EUR is set equal to its nominal equivalent at 2001:1).
- $g =$ structural government deficit (as percent of potential GDP as computed by the OECD).
- $g^* =$ TCW (or EMU) weighted structural government deficit (as percent of potential GDP).
- $GDP =$ Real gross domestic product (s.a.).
- $GDP^* =$ TCW (or EMU) weighted gross domestic product (s.a.).
- $old =$ people 50-64 years old in relation to 15-65 years old.
- $P =$ Swedish consumer price index.
- $P^* =$ A TCW (or EMU) weighted consumer price index.
- $pr =$ log of labor productivity (GDP per hours worked).
- $P_{UND} =$ The UND1X core inflation price index is our measure of inflation in the Phillips curve.
- $q = P_X/P_M$, the terms of trade computed as export deflator over import deflator.
- $r =$ replacement ratio: maximum daily unemployment compensation divided by eight times the average hourly wage.
- $TCW =$ A competitiveness weighted nominal effective exchange rate index (18 November 1992 = 100).
- $\theta = \ln\left[(1+\tau)\left(\frac{1+s}{1-t}\right)\right]$, where $\tau$ is direct effects on the CPI from indirect taxes and subsidies, $s$ is pay-roll tax and $t$ is income tax.

- $u = OU/TLF$ is the rate of unemployment, where $OU$ = open unemployment and $TLF$ = total labor force.
- $(y^* - y^{n*})$ = Foreign cyclical demand, where potential output is computed as the HP-filtered series of $GDP^*$.
- $young$ = people 15-24 years old in relation to 15-65 years old.

# References


[1] Alexius, A. (2001). Sources of real exchange rate fluctuations in the Nordic countries. *Scandinavian Journal of Economics* 103.

[2] Andersson, A. and P. Österholm (2001). The impact of demography on the real exchange rate. Working Paper No. 2001:11, Uppsala University.

[3] Apel, M. and P. Jansson (1999). System estimates of potential output and the NAIRU. *Empirical Economics* 24(3).

[4] Assarsson, B. and P. Jansson (1998). Some further evidence on hysteresis in unemployment: The case of Sweden. *Applied Economics Letters* 5.

[5] Ball, L. and N.G. Mankiw (1995). What do budget deficits do? in *Budget deficits and debt: issues and options*, a symposium sponsored by The Federal Reserve Bank of Kansas City, Jackson Hole, Wyoming.

[6] Ball, L. and N.G. Mankiw (2002). The NAIRU in theory and practice. NBER Working Paper No. 8940.

[7] Barwell, R. (2000). Age structure and the UK unemployment rate. Working Paper No. 124, Bank of England.

[8] Bean, C. (1994). European unemployment: a survey. *Journal of Economic Literature* 32.

[9] Bergvall, A. (2002). What determines real exchange rates? The Nordic countries. Working Paper 2002:15, Uppsala University.

[10] Blanchflower, D.G. and A.J. Oswald (1994). *The wage curve.* MIT Press, Cambridge, Massachusetts.

[11] Bucht, C., N. Gottfries, and M. Lundin (2002). Why don't prices fall in a recession? Financial constraints, investment, and customer relations. Working Paper 2002:3, Uppsala University.

[12] Calmfors, L. (1985). Work sharing, employment and wages, *European Economic Review* 27.

[13] Calmfors, L. and A. Forslund (1990). Wage formation in Sweden. In L. Calmfors (ed.) *Wage formation and macroeconomic policy in the Nordic countries.* SNS and Oxford University Press, Oxford.

[14] Calmfors, L., A. Forslund, and M. Hemström (2002). Does active labor market policy work? Lessons from the Swedish experiences, Working Paper 2002:4 Institute for Labor Market Policy Evaluation.

[15] Calmfors, L. and H. Lang (1995). Macroeconomic effects of active labour market programmes in a union wage-setting model. *The Economic Journal* 105.

[16] Calmfors, L. and R. Nymoen (1990). Nordic employment, *Economic Policy* 5(11).

[17] Clark and MacDonald (2000). Filtering the BEER: a permanent and transitory decomposition, IMF Working Paper No. 144.

[18] Davidson, R. and J.G. MacKinnon (1993). *Estimation and inference in econometrics.* Oxford University Press.

[19] Dungey, M. (2002). Identifying terms of trade effects in real exchange rate movements: evidence from Asia. Paper presented at the 24th International Conference on Asian Economic Studies, Beijing University, May 26-29, 2002. Mimeo, Australian National University.

[20] Elmeskov, J. (1994). Nordic unemployment in a Nordic perspective. *Swedish Economic Policy Review* 1(1-2).

[21] Engel, C.M. (1999). Accounting for real exchange rate changes. *Journal of Political Economy* 107.

[22] Forslund, A. (1995). Unemployment - is Sweden still different? *Swedish Economic Policy Review* 2(1).

[23] Forslund, A. and A.-S. Kolm (2000). Active labor market policies and real-wage determination - Swedish evidence, Working Paper 2000:7, Office of Labor Market Policy Evaluation.

[24] Ghironi, F. (2000). Towards new open economy macroeconometrics. Mimeo, Department of Economics, Boston College.

[25] Greene, W.H. (1993). *Econometric Analysis*, 2nd ed. Prentice-Hall, Englewood Cliffs, NJ.

[26] Hakkio, C.S. (1996). The effect of budget deficit reduction on the exchange rate, *Economic Review,* Federal Reserve Bank of Kansas City.

[27] Harvey, A.C. (1989). *Forecasting, structural time series models and the Kalman filter*, Cambridge University Press.

[28] Haskel, J. and H. Wolf (2001). The law of one price - a case study. NBER Working Paper No. 8112.

[29] Hendry, D. and K. Juselius (1999). Explaining Cointegration Analysis: Part I. Mimeo.

[30] Holden, S. and R. Nymoen (2001). Measuring structural unemployment: NAWRU estimates in the Nordic countries. Mimeo, University of Oslo, Norway.

[31] Holmlund, B. (1989). Wages and employment in unionized economies: theory and evidence, in Holmlund, B., K.-G. Löfgren, and L. Engström, *Trade unions, employment, and unemployment duration.* Oxford University Press.

[32] Homlund, B. (1993). Arbetslöshetskrisen - konjunkturfenomen eller systemfel? Appendix 12 to SOU 1993:16, Lindbeck, A. et el *Nya villkor för ekonomi och politik.* Allmänna förlaget, Stockholm.

[33] Jaeger, A. and M. Parkinson (1994). Some evidence on hysteresis in unemployment rates. *European Economic Review* 38.

[34] Jonung, L., ed. (2003). *På jakt efter ett nytt ankare.* SNS Förlag.

[35] Joyce, M. and S. Wren-Lewis (1991). The role of the real exchange rate and capacity utilization in convergence to the NAIRU, *Economic Journal* 101.

[36] Klein, M.W., S. Schuh, and R.K. Triest (2002). Job creation, job destruction and the real exchange rate. *Journal of International Economics* 56.

[37] Lane P.R. (2001). The new open macroeconomics: a survey. *Journal of International Economics* 54.

[38] Lane P.R. and G.M. Milesi-Ferretti (2000). The transfer problem revisited: net foreign assets and real exchange rates, CEPR Discussion Paper No. 2511.

[39] Laubach, T. (2001). Measuring the NAIRU: evidence from seven economies. *The Review of Economics and Statistics* 83(2).

[40] Laubach, T. and J.C. Williams (2001). Measuring the natural rate of interest. Mimeo, Board of Governors of the Federal Reserve System.

[41] Layard, R., S. Nickel and R. Jackman (1991). *Unemployment: macroeconomic performance and the labour market.* Oxford University Press, Oxford

[42] Lindblad, H. (1997). Persistence in Swedish unemployment rates, Working Paper 1997:3, Dept. of Economics, University of Stockholm.

[43] Lindh, T. and B. Malmberg (1999). Age structure and the current account - a changing relation? Working Paper 1999:21, Dept. of Economics, Uppsala University.

[44] MacDonald R. (2000). Concepts to calculate equilibrium exchange rates: an overview. Discussion Paper 3/00, Deutsche Bundesbank.

[45] Masson, P.R., J. Kremers, and J. Horne (1994). Net foreign assets and international adjustment: the United States, Japan, and Germany. *Journal of International Money and Finance,* 13(1).

[46] Nilsson, K. (2002). Do fundamentals explain the behavior of the real effective exchange rate? Working paper no. 78, National Institute of Economic Research, Sweden.

[47] Obstfeld, M. (2001). International Macroeconomics: Beyond the Mundell-Fleming Model. *IMF Staff Papers* Vol. 47, Special Issue, 1-39.

[48] Persson, T. and L.E.O. Svensson (1985). Current account dynamics and the terms of trade: Harberger-Laursen-Metzler two generations later. *Journal of Political Economy* 93.

[49] Phillips, P.C.B. and B.E. Hansen (1990). Statistical inference in instrumental variables regression with I(1) processes. *Review of Economic Studies* 57.

[50] Salemi, M.K. (1999). Estimating the natural rate of unemployment and testing the natural rate hypothesis, *Journal of Applied Econometrics* 14.

[51] Turner, D., L. Boone, C. Giorno, M.Meacci, D. Rae and P. Richardson (2001). Estimating the structural rate of unemployment for then OECD countries, *OECD Economic Studies* No. 33, 2001/2.

**Figure 1. Open unemployment as percent of total labor force (seasonally adjusted and unadjusted series)**

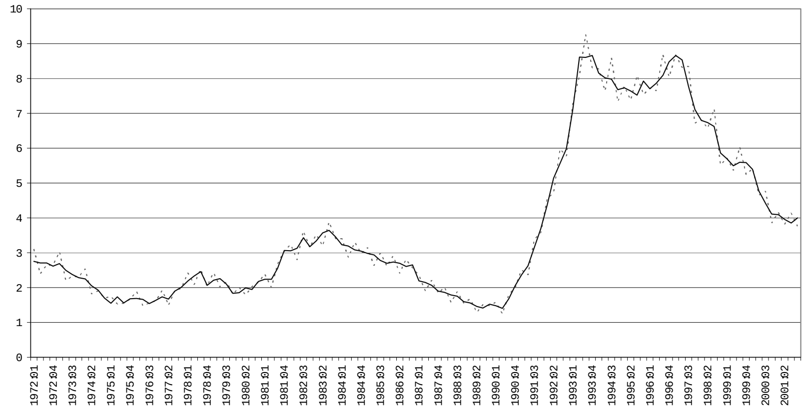



**Figure 2. Accommodation rate (seasonally adjusted and unadjusted series, percent of total unemployment)**

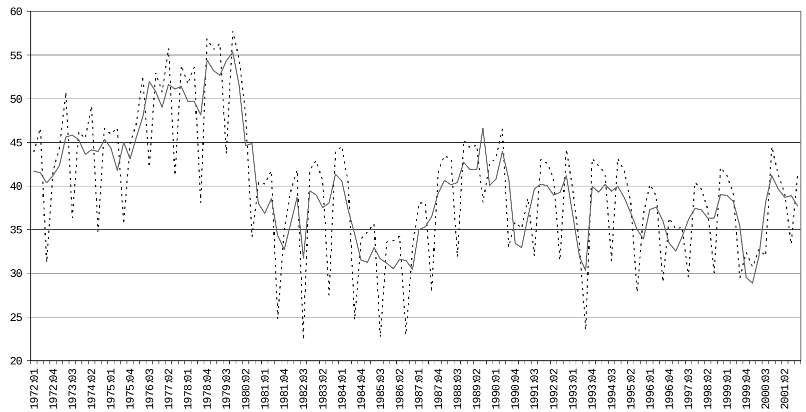



**Figure 3. Replacement ratio (seasonally adjusted and unadjusted series)**

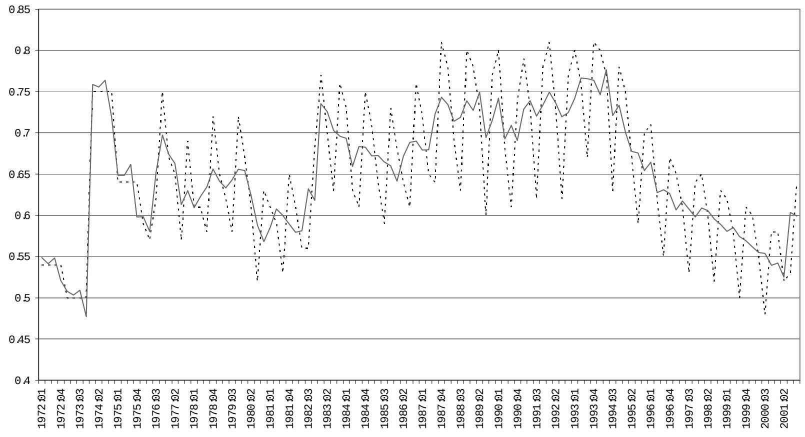



**Figure 4. Tax wedge index**

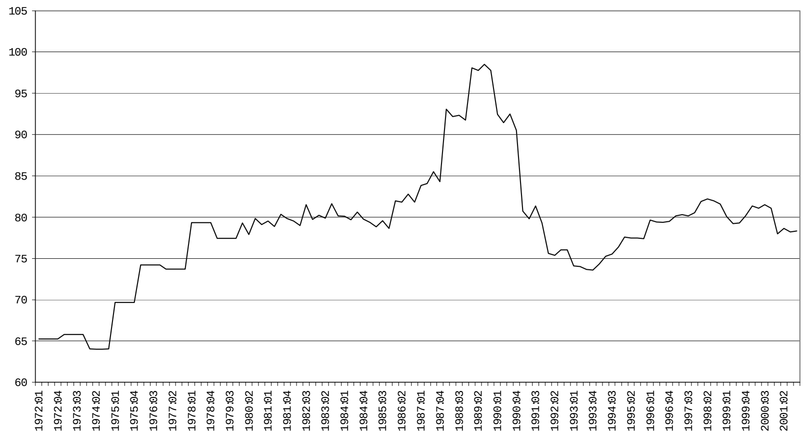


**Figure 5. The quarterly change in the age share of people of working age (in percent)**

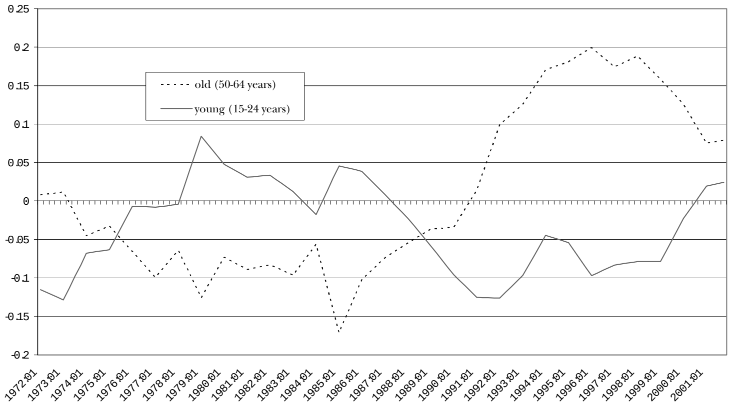



**Figure 6. Real effective exchange rates**

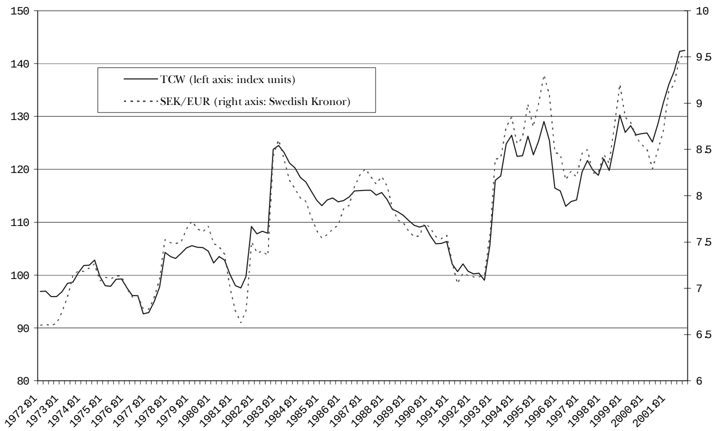



**Figure 7. Change in the relative share of savers**

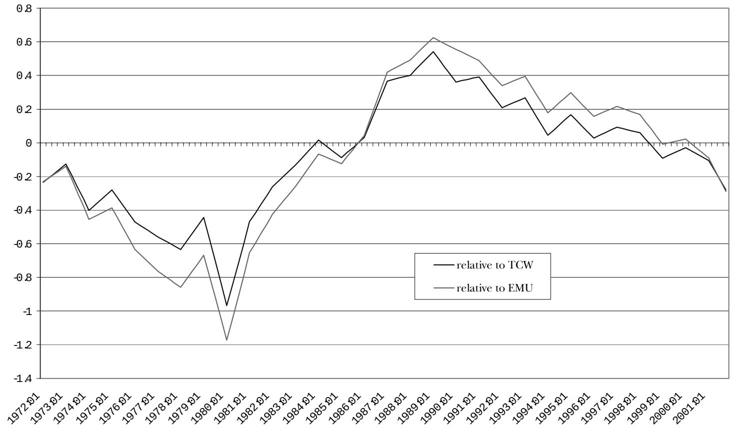



**Figure 8. Terms of trade (Px/Pm)**

**Figure 9. Structural budget deficits as percent of potential GDP**

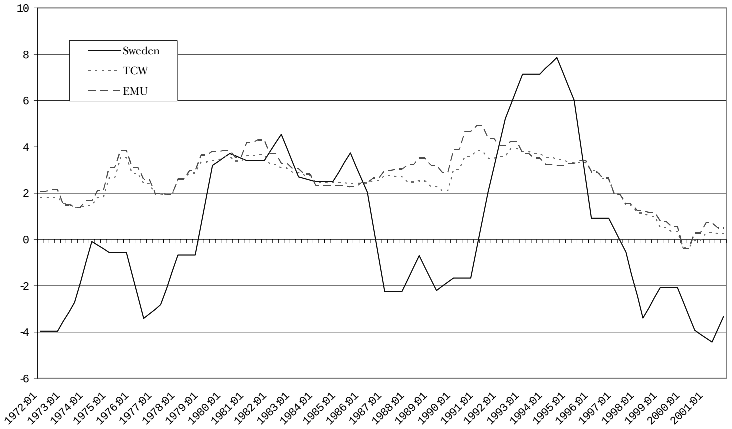



**Figure 10. Foreign output gaps (volume index units)**

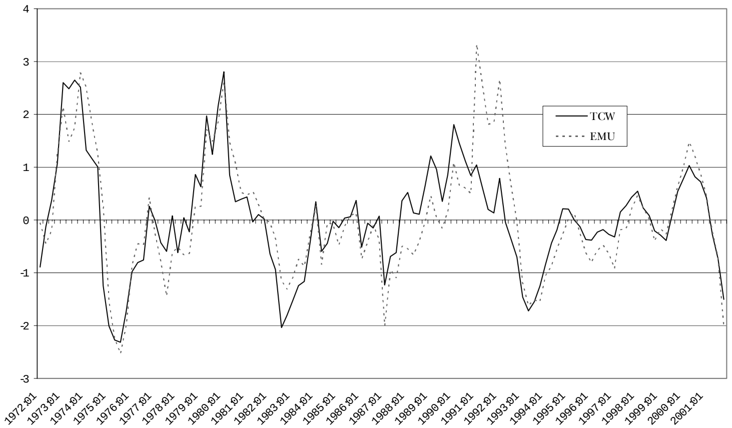



**Figure 11. Quarterly change in annual inflation (in percent)**

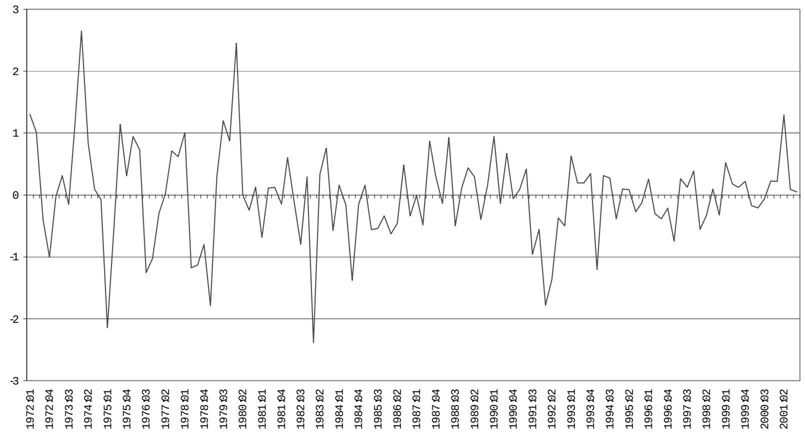


**Figure 12. Import price shocks**

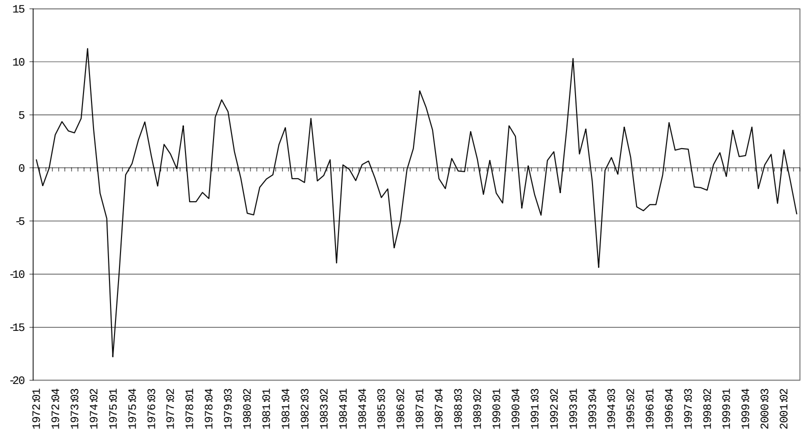


**Figure 13. Productivity shocks**

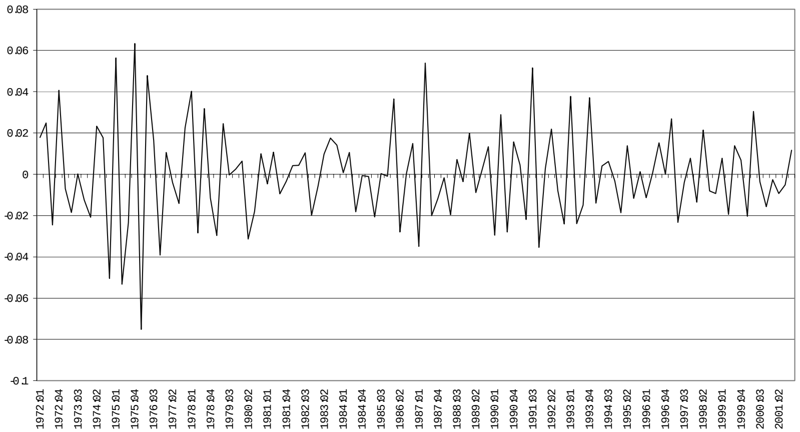



**Figure 14. NAIRU and cyclical unemployment: Model 1**

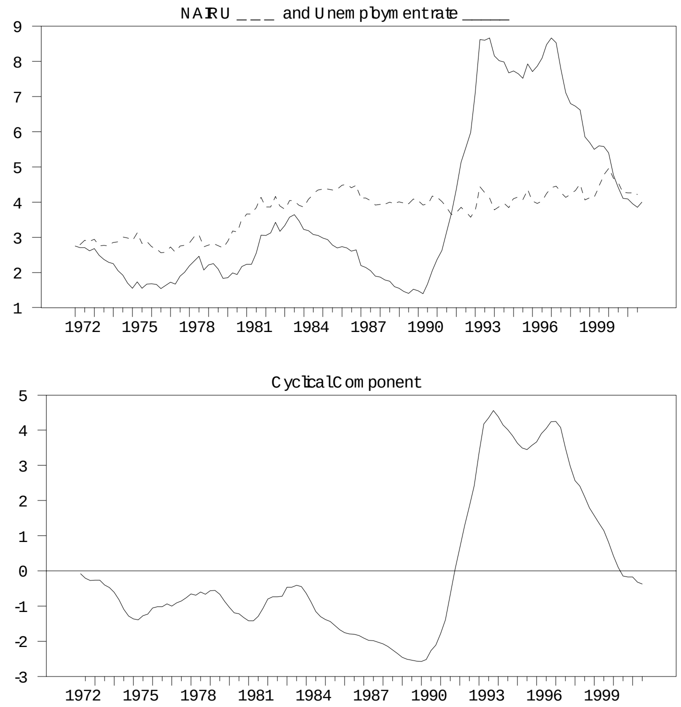


**Figure 15. Real equilibrium exchange rate: Model 1**

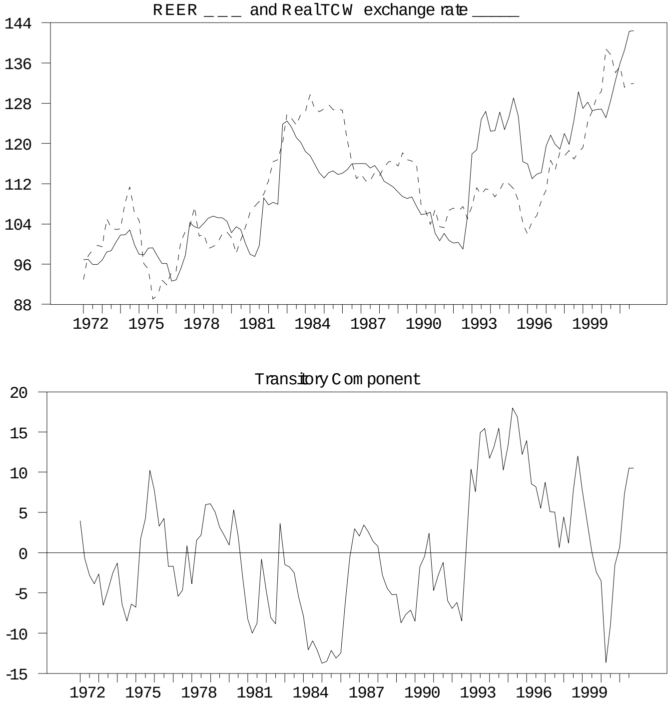



**Figure 16. Fundamental exchange rate: Model 1**

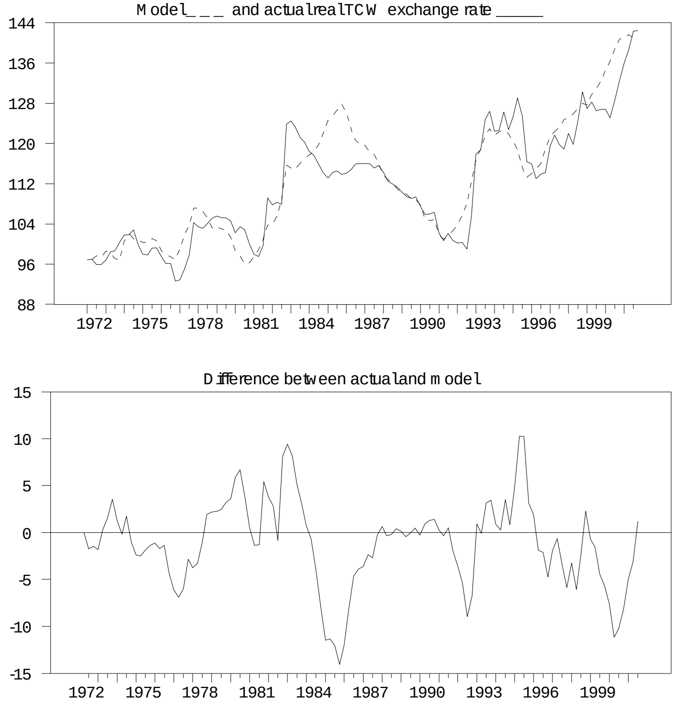


**Figure 17. Exchange rate components: Model 1**

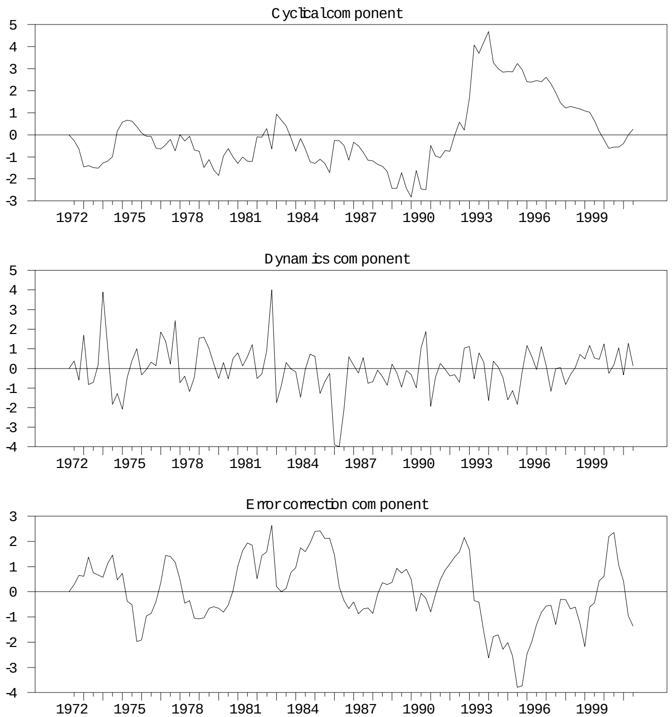



**Figure 18. Fundamental minus cycle: Model 1**

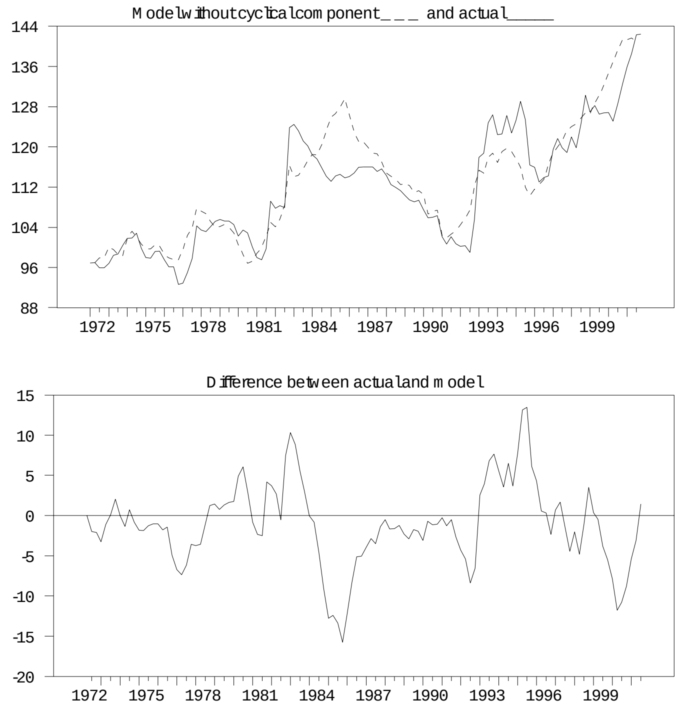


**Figure 19. Standardized residuals: Model 1**

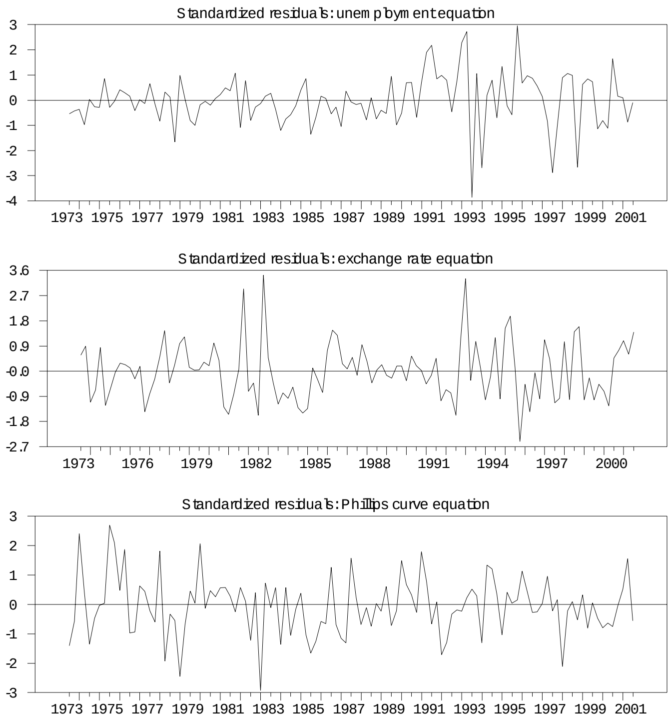



**Figure 20. NAIRU and cyclical unemployment: Model 2**

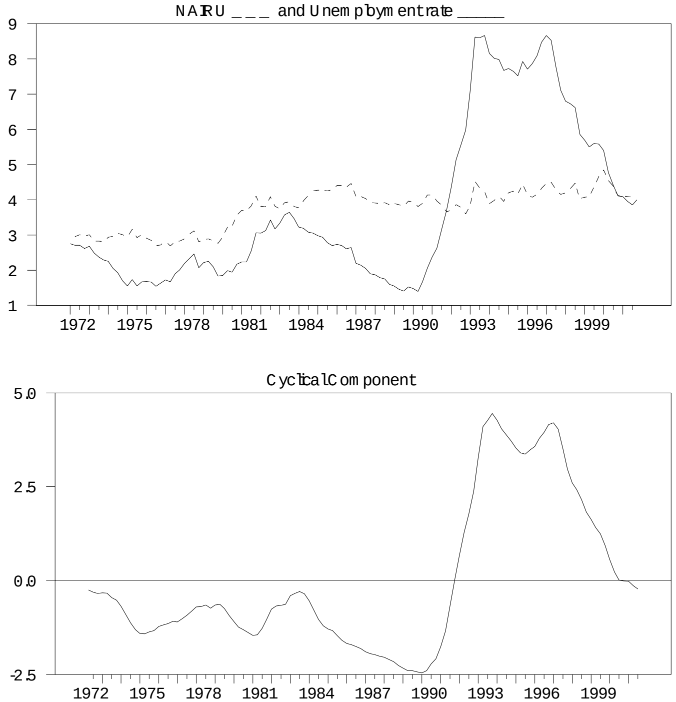


**Figure 21. Real equilibrium exchange rate: Model 2**

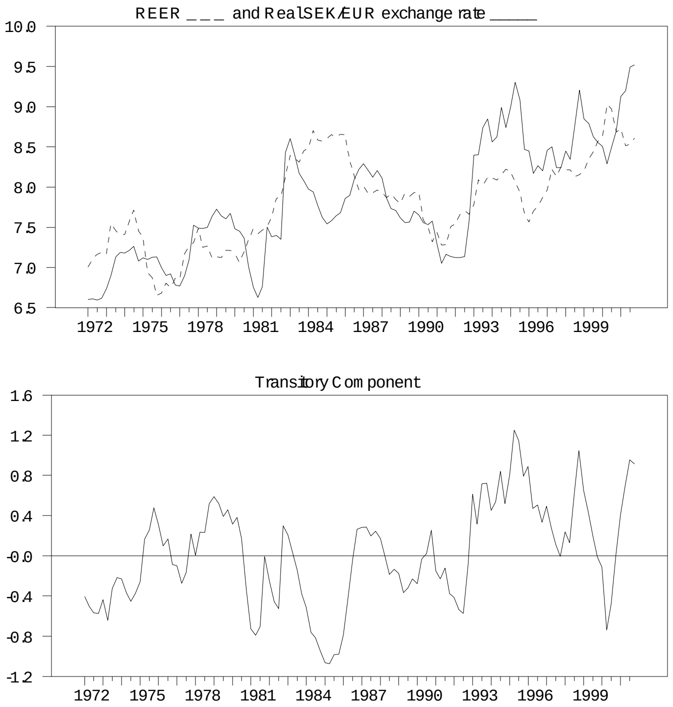



**Figure 22. Fundamental exchange rate: Model 2**

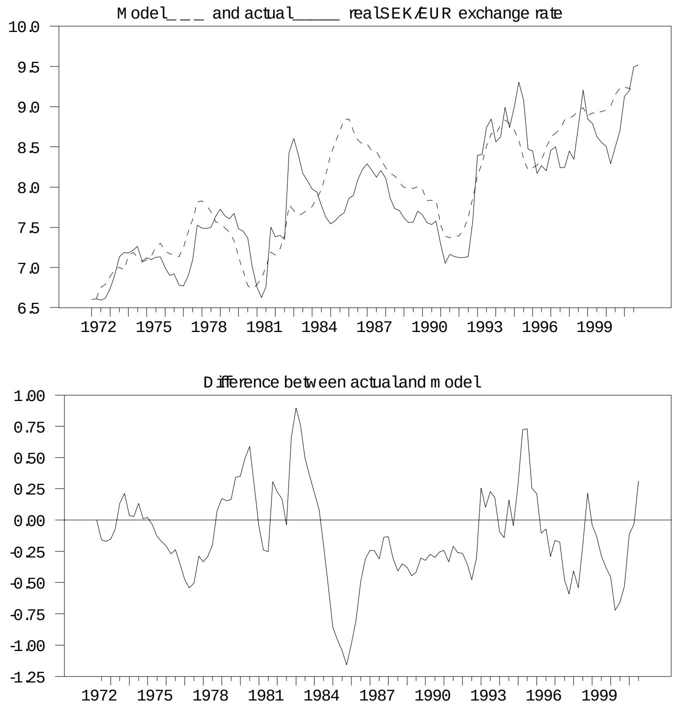


**Figure 23. Exchange rate components: Model 2**

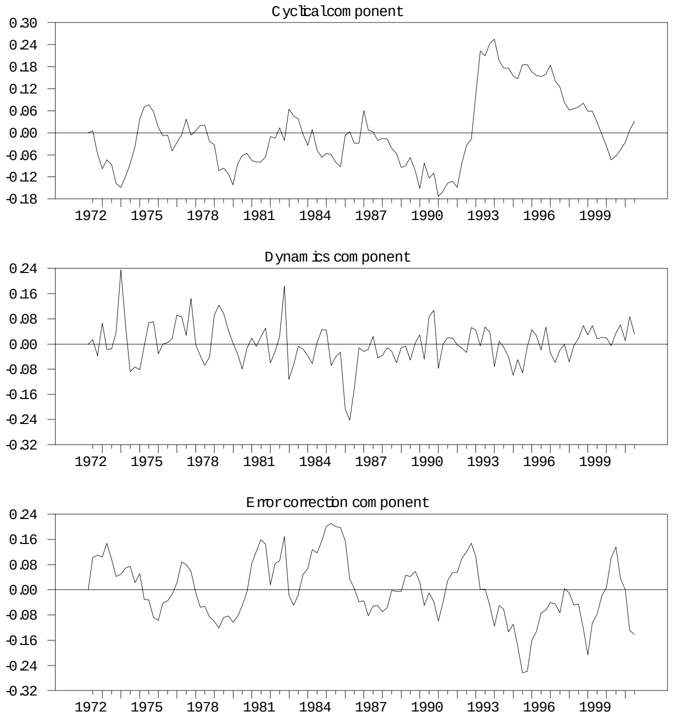



**Figure 24. Fundamental minus cycle: Model 2**

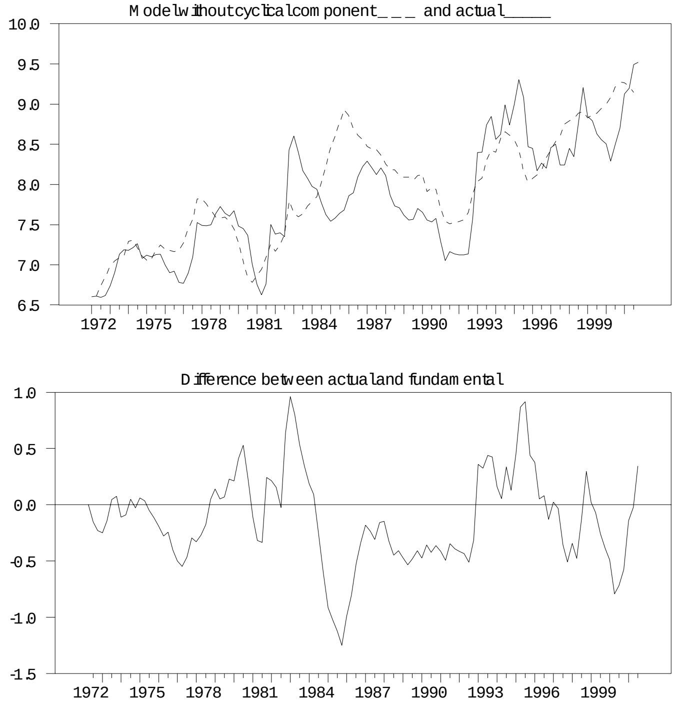
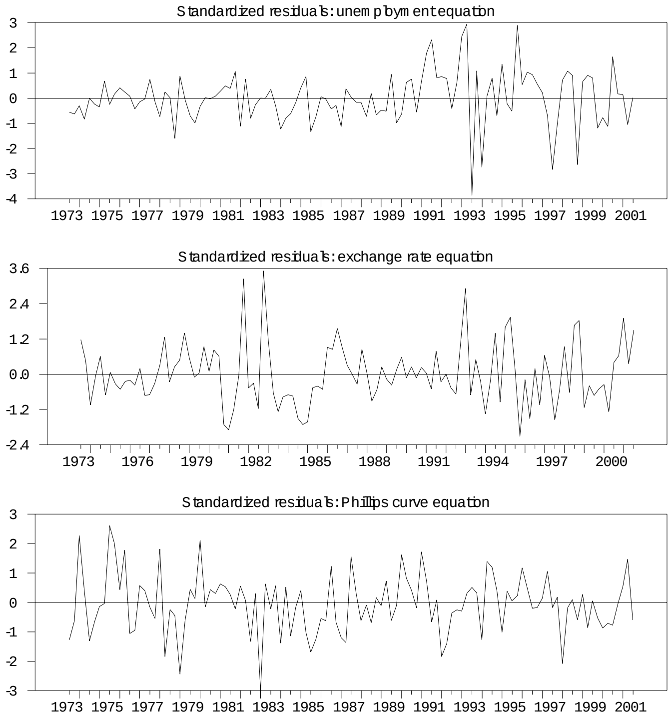


**Figure 25. Standardized residuals: Model 2**



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