U.S. natural rate dynamics reconsidered.*

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Abstract

Several features of the U.S. natural rate of unemployment are reconsidered through specification and testing of econometric models. Traditionally, the choice has been between a wage Phillips curve model, PCM, or an equilibrium correction wage curve model, WECM. The models proposed in this paper feature extended equilibrium correction which reduces the consequences for natural rate dynamics of choosing between wage models. In order for the difference between PCM and WECM to become important, the extended equilibrium correction mechanism must be 'switched off' by restrictions. These restrictions are rejected when tested. The analysis supports the view that natural rates are system dependent—rather than being derivatives of a single (wage) Phillips curve. The econometric model indicates a reduction of the natural rate in the course of the 1990s, due to low worker bargaining power and other structural changes. The estimated reduction is approximately $0.5 - 0.8$ percentage points, which is less than existing results based on Phillips curve estimation.

Keywords: *US unemployment, natural rate, NAIRU, equilibrium unemployment, equilibrium correction, Phillips curve.*

JEL classification: *C52, E24, E31, E37, J31.*

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1 Introduction

There is little doubt that the natural rate of unemployment counts as one of the most successful concepts in the history of macroeconomics. Governments and international organizations customarily refer to the natural rate, or to the related concept of the "non-accelerating inflation rate of unemployment", NAIRU, calculations in their discussions of employment and inflation prospects[1], and the existence of a natural rate is also used to rationalize current monetary policy.[2] In the US in particular, the empirical wage Phillips curve provides the operational method for estimation of the natural rate, see Fuhrer (1995), Gordon (1997) and Blanchard and Katz (1999).[3] Thus, the empirical wage Phillips curve is also the basis of the consensus view that the US natural rate of unemployment fell during the last decade of the previous century, see e.g., Blanchard (2005, pp 177-178). In this chapter we analyse the US natural rate from different methodological angles.

The crux of the natural rate hypothesis is that there is only one unemployment rate which can be reconciled with nominal stability of the economy, and that the natural rate equilibrium is asymptotically stable. This leads to several important questions that can only be answered by modelling the rate of unemployment, and thereby its steady state, as a system property. In particular we need to know the economic mechanisms which stabilize the actual unemployment rate around its mean, and what kind of shocks to the system that are likely to change the long-run mean.

We present two models which are often contrasted in the way economists think about the natural rate: the standard North-American model of the natural rate with a wage Phillips curve, PCM, and a model with wage equilibrium correction, WECM. We then show that whether the PCM and the WECM really are the polar cases in terms of natural rate dynamics that for example Blanchard and Katz (1999) make them out to be, depends on the specification of other parts of the macroeconomic model.

At a general level it stands to reason that the degree of mean reversion of the rate of unemployment is system dependent, rather than being strongly conditioned by a small set of restrictions on a single (wage) equation. Other essential features of dynamics, like cointegration and equilibrium correction are known to be system properties, as stressed by Hendry (1995, Ch 8.6), and unemployment dynamics can be seen as special case. From this starting point, we show in section 2 that equilibrium correction elsewhere in the model, for example in price setting, implies that the dynamic properties of the PCM and WECM are qualitatively similar, in particular for the rate of unemployment. We refer to this result as *extended equilibrium correction* since it shows that the issue about mean reverting behaviour of the rate of unemployment is just as much a question about equilibrium correction elsewhere

[1] See Elmeskov and MacFarlan (1993), Scarpetta (1996) and OECD (1997, Chapter 1) for examples, and e.g., Bårdsen et al. (2005, Ch 1.3) for discussion of the concepts.

[2] See the discussion in King (1998) for a central banker's views.

[3] In this chapter, the asymptotically stable equilibrium rate of unemployment can correspond to a natural rate, independent of the foreing steady state rate of inflation, or a to NAIRU, which depends on such an inflation rate, see 2.1 and 2.2, but often we will simply use the term natural rate for brevity.

in the system as in the wage equation. In section 3 these points are illustrated empirically by dynamic simulation of different econometric models of the US rate of unemployment and its determinants.

The econometric test results do not reject the view that extended equilibrium correction is a feature to be reckoned with. We demonstrate that the impact of choosing a Phillips curve equation or an equilibrium correction equation for wages on the natural rate dynamics may have become overstated by the earlier literature. Only if the extended equilibrium correction mechanisms are omitted, which statistical tests indicate that they should not be, does the sharp distinction between the PCM and the WECM come into full play.

In a wider interpretation, the econometric models allow a larger role for aggregate demand than in the standard model of the U.S. natural rate. For example, the results are consistent with the view that persistent demand shocks may affect the rate of unemployment beyond the period of the business cycle. In the light of our empirical results, the comparative stability of the US natural rate as the joint outcome of demand effects and the flexibility of the US labour market. That said, our model includes proxies for institutional developments and regime shifts, i.e., changes which also standard theory predicts should have an impact on the equilibrium rate. In section 5, we discuss the stability of the natural rate in the period from 1990 to 2004. As noted above, the received view is that the natural rate was significantly reduced in the period. Our results confirm that a reduction may has taken place, but the estimated reduction is smaller than in existing studies. According to the model, unusual low worker bargaining power is one of the explanations for the lower natural rate. Section 6 concludes.

2 A stylized dynamic system

The main variables in a linearized model of natural rate are the following: wages per hour, denoted w_t, a price level variable, p_t, labour productivity, z_t, and a rate of unemployment, u_t. The PCM and the WECM are consistent with the following two assumptions about the temporal data properties:

A1. Non-stationarity: w_t has a stochastic trend, while $\Delta w_t = w_t - w_{t-1}$ has no trend. Hence $w_t \sim \mathsf{I}(1)$, reading *integrated of degree 1*. Likewise $p_t \sim \mathsf{I}(1)$ and $z_t \sim \mathsf{I}(1)$ as well.

A2. Cointegration: $w_t - p_t - \iota z_t - \mu_w \sim \mathsf{I}(0)$, with $0 \leq \iota \leq 1$, and $u_t - \mu_u \sim \mathsf{I}(0)$, possibly after removal of shifts in the respective means μ_w and μ_u.

The first assumption, A1, is essentially an assumption of local, or stochastic, trends in wages, prices and productivity variables. Hence, expected growth rate of e.g. productivity is a constant parameter, while the actual growth rate is stochastic. The alternative assumption would be a global or deterministic trend, which is less appealing on the grounds of realism. A variable trend assumption is tantamount to assuming that the variables become stationary after differentiation, and A1 states that the analysis is based on the premise that it is sufficient to difference w_t, p_t and z_t once to obtain stationarity.

Economic theory implies cointegration. In A2 above, there are two cointegration relationships. The first asserts the stationarity of the productivity corrected real wage. The second assumption in A2, $u_t - \mu_u \sim \mathsf{I}(0)$, says that the rate of unemployment is stationary with a constant mean. However, in our interpretation, the mean can be conditional on regime shifts which can be represented by either deterministic variables or by strongly exogenous stochastic forcing variables. A2 is also consistent with a 'wage-curve' between the real wage, the rate of unemployment (and productivity), see Blanchflower and Oswald (1994).

Given the assumption that $u_t - \mu_u \sim \mathsf{I}(0)$ after removal of structural breaks, there exists a time series model of u_t which is asymptotically stable.[4] As pointed out above, the natural rate hypothesis implies only one unemployment rate which can be reconciled with nominal stability of the economy, and that the natural rate equilibrium is asymptotically stable. Hence μ_u can be interpreted as the mean of the rate of unemployment, in other words, the equilibrium value which the rate of unemployment returns to asymptotically after a shock. To know the economic mechanisms which stabilize the actual unemployment rate around its mean, and what kind of shocks to the system are likely to change the mean, we therefore model the rate of unemployment, and thereby its mean, as a system property.

The two theories are consistent with a restricted cointegration vector where $\iota = 1$ so that $w_t - p_t - z_t - \mu_w \sim \mathsf{I}(0)$. A stylized model which encompasses both theories is:

$$(1) \qquad \Delta w_t = \beta_{w0} - \beta_{w1} u_t + \beta_{w2} \Delta z_t + \beta_{w3} \Delta p_t - \underset{<1}{\theta_w} (w - p - z)_{t-1} + \varepsilon_{w,t},$$

$$(2) \qquad u_t = \beta_{u0} + \underset{<1}{\beta_{u1}} u_{t-1} + \underset{\geq 0}{\beta_{u2}} (w - p - z)_{t-1} - \beta_{u3} x_{u,t} + \varepsilon_{u,t},$$

$$(3) \qquad \Delta p_t = \zeta(\Delta w_t - \Delta z_t) + (1 - \zeta) \Delta pi_t + \varepsilon_{p,t},$$

$$(4) \qquad \Delta z_t = g_z + \varepsilon_{z,t},$$

$$(5) \qquad \Delta pi_t = g_{pi} + \varepsilon_{pi,t},$$

where imported price growth Δpi_t is in terms of domestic currency. With $\theta_w = 0$, equation (1) is the wage Phillips curve which is typically found to represent the relationship between aggregate (annual) wage inflation, and unemployment in the United States, see for example Blanchard and Katz (1999). The role of inflation in the wage setting process is an important issue. Often Δp_t is replaced by expected inflation, Δp_t^e or Δp_{t+1}^e, which are in turn approximated by, or instrumented by Δp_{t-1}, but the simultaneous equations specification in (1) is convenient for our purpose. Δz_t represents a possible effect of labour productivity on wage growth. $\varepsilon_{w,t}$ denotes a disturbance term, which is assumed to be normally distributed with a constant standard deviation, and (for simplicity) also uncorrelated with the other disturbances of the model ($\varepsilon_{u,t}$,$\varepsilon_{p,t}$, $\varepsilon_{z,t}$ and $\varepsilon_{pi,t}$).

Wage bargaining models imply equilibrating mechanism whereby wages are directly influenced by profits, see Forslund et al. (2008), in addition to the indirect channel through the unemployment rate. This implies $0 < \theta_w < 1$ and $\beta_{w1} > 0$

[4] Formally, the solution of the linear difference equation of u_t is unique when it has no roots on the unit circle, and the mean of u_t is thus also unique and time independent. Hence the model of (linear) hysteresis of Blanchard and Summers (1986) is inconsistent with A1 and A2.

in (1)[5] Equilibrium correction models for wages and prices have a long history in econometrics. Sargan (1964,1980) coined the term, and saw the formulation as an extension of the original Phillips curve. Later, it has been established that there is also a close correspondence between modelling wages in terms of cointegration and equilibrium correction, and a theoretical framework of the wage bargaining type, see Nymoen (1989, 1991) and Bårdsen et al. (2005, Ch. 4-6).

The rate of unemployment is modelled in (2) as rising when real wages are high relative to productivity, corresponding to standard microeconomic predictions of firm behaviour. The "catch-all" variable $x_{u,t}$ represents (a vector) of other factors than wages which affect the rate of unemployment. It might contain conventional demand side variables (foreign demand, changes in the domestic savings rate, and policy instruments), but also shocks that affect the supply of labour at the going real wage (for example demographic changes).

The three last equations of the PCM are even more stylized than the two first. Equation (3) gives price inflation as determined by the growth rate of domestic unit labour costs and of import prices (in dollars). Equations (4) and (5) specify productivity and import prices as random walks with expected growth rates g_z and g_{pi}. Imported price growth Δpi_t is in terms of domestic currency and the formulation in (5) is consistent with assuming that there is no pricing-to-market.

2.1 Phillips curve dynamics

The PCM is defined by setting $\theta_w = 0$, thus omitting wage equilibrium correction. Nevertheless, the PCM is an equilibrium correction system. To clarify the implication of this, use equation (3) to substitute out the Δp_t term in the wage PCM, giving a semi reduced form equation for wage growth:

$$\Delta w_t = b_{w0} - b_{w1} u_t + b_{w2} \Delta z_t + b_{w4} \Delta pi_t + \varepsilon'_{w,t}, \tag{6}$$

where $b_{w1} = \beta_{w1}/(1 - \beta_{w3}\zeta)$, $b_{w2} = (\beta_{w2} - \beta_{w3}\zeta)/(1 - \beta_{w3}\zeta)$ and $b_{w4} = \beta_{w3}(1 - \zeta)/(1 - \beta_{w3}\zeta)$. Next, substitute u_t in (6) by the right hand side of equation (2), and note that the equilibrium correction coefficient of the lagged wage level term in the Δw_t equation becomes $-\beta'_{w1}\beta_{u2}$. Hence, as long as the PCM *system* displays both an effect from unemployment on wage growth, $-\beta_{w1} < 0$, *and* an effect of the wage level on unemployment, $\beta_{u2} > 0$, the dynamics of wages and unemployment are of the equilibrium correction type. Since equilibrium correction implies cointegration, and since cointegration corresponds to dynamic stability, it follows that a sufficient condition for dynamic stability is that $-\beta_{w1} < 0$ and $\beta_{u2} > 0$ hold *jointly*.

Formal dynamic analysis of (1)-(5) confirms that, subject to $\theta_w = 0$, $-\beta_{w1} < 0$ and $\beta_{u2} > 0$ the PCM system has two stable roots and three unit roots. The unit roots represent the I(1)-ness of the price level index p_t, productivity z_t, and the import price index, pi_t. Consistent with A2, the two equilibrium values, corresponding

[5] We abstract from negative (but stable) values of θ_w with reference to nominal wage rigidity.

to the means of the wage-share and unemployment are given by:

$$\mu_{u,PCM} = \frac{\beta_{w0}}{\beta_{w1}} + \frac{(\beta_{w2}-1)}{\beta_{w1}} g_z + \frac{(\beta_{w3}-1)}{\beta_{w1}} g_{pi}, \text{ and} \tag{7}$$

$$\mu_{w,PCM} = -\frac{\beta_{u0}}{\beta_{u2}} + \frac{(1-\beta_{u1})}{\beta_{u2}}\mu_u + \frac{\beta_{u3}}{\beta_{u2}} x_u, \tag{8}$$

where we have added the PCM acronym to the subscript of the two means. The case of the vertical long-run Phillips curve is represented by $\beta_{w3} = 1$, and implies that $\mu_{u,PCM}$ is independent of inflation, i.e., the usual implication of dynamic homogeneity of the wage Phillips curve. With $\beta_{w3} = 1$ imposed, the steady state unemployment rate coincides with the expression for the natural rate of unemployment that most economists would write down when asked.

It remains one of the great appeals of the PCM that the NAIRU, $\mu_{u,PCM}$ only depends of the parameters of one of the equation of the system. Estimation of a wage (or price) Phillips curve is the dominant strategy for estimation of the natural rate, and Staiger et al. (1997) is an important contribution.[6]. However, the standard approach does not address another important question: whether the estimated natural rate corresponds to an asymptotically stable equilibrium, see Bårdsen et al. (2005, Ch 4.2).

2.2 Wage equilibrium correction dynamics

Wage equilibrium correction, $0 < \theta_w < 1$ represents an adjustment mechanism which stabilizes wages at any given rate of unemployment. The two equilibrating mechanisms supporting the cointegration properties of $w_t - p_t - z_t - \mu_w \sim \mathsf{I}(0)$ and $u_t - \mu_u \sim \mathsf{I}(0)$ mean that the speed of adjustment will be faster in the case of the WECM than in the PCM case. Hence, if the PCM system is dynamically stable, then the WECM system is also stable, *a fortiori*. Another difference from the PCM is that the natural rate is a genuine system property in WECM—it can no longer be retrieved from the wage equation alone. Solving for the steady-state rate of unemployment gives

$$\mu_{u,WECM} = \frac{\theta_w\left\{\beta_{uo} + \beta_{u3}x_u\right\} + \beta_{u2}\left\{\beta_{w0} + (\beta_{w2}-1)g_z + (\beta_{w3}-1)g_{pi}\right\}}{\theta_w(1-\beta_{u1}) + \beta_{w1}\beta_{u2}}. \tag{9}$$

Note that a permanent change in the exogenous variable x_u (a shock which does not disappear) has an impact on the equilibrium rate of unemployment in this model, while it does not affect the PCM natural rate. Dynamic homogeneity, $\beta_3 = 1$, also in the WECM case removes imported inflation g_{pi} from the expression of the steady state rate of unemployment. The implication that permanent changes on the "demand side" of the economy (in a parameter like β_{uo} or in the variable x_u) is robust to the dynamic homogeneity restriction though.

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[6]Blanchard and Katz (1997) review the standard model of the natural rate in the following way (p. 60): *U.S. macroeconometric models...determine the natural rate through two equations, a "price equation" ...and a "wage equation"*. The "wage equation" specified in Blanchard and Katz is identical to our equation (1), albeit without the productivity term, and the "price equation" is the same as (3) but without the productivity and import price terms.

The appearance of the labour demand shift variable x_u in the WECM equilibrium unemployment rate fits the idea that relatively permanent changes in unemployment might be due to structural breaks that occur intermittently, in line with our maintained view of the rate of unemployment as $\mathsf{I}(0)$ but subject to (infrequent) structural breaks. The PCM, while not inconsistent with this view, nevertheless would attribute the mean-shifting capability only to those structural changes which occur distinctly on the supply side (through shifts in the Phillips curve intercept β_{w0}). The difference between the PCM and WECM is thus one of degree, not of principle. The WECM might be said to allow the longer list of candidates for regime shifts—from different sectors of the macro economy. For example, if we associate the equations for wage, prices and productivity with the supply side of the macro economy and (2) with the demand side, then (9) allows permanent demand shocks to affect the equilibrium rate through x_u.

2.3 Extended equilibrium correction dynamics

Both the PCM and the WECM are equilibrium correction models of the natural rate. The difference is that the PCM implies a more restrictive stabilization process than the WECM. In the PCM, equilibrium correction takes place in the unemployment equation alone. The WECM has an additional stabilization mechanism in the wage equation itself. Moreover, the PCM is a special case of the WECM, and $\theta_w = 0$ implies , $\mu_{u,WECM} = \mu_{u,PCM}$.

In the two models, the price setting equation has been kept deliberately simple, in so-called differenced form. As pointed out by Hendry et al. (1984), an equation in differenced form implies that the variable in question, the price level in our case, is always on its steady-state trajectory. This is unrealistic, goes against theory (e.g., Blanchard (1987)), and is an unnecessary constraint on an empirical model. Modern models of the wage-price inflation spiral instead model *both* wage and price inflation as influenced by past equilibria, see e.g., Nymoen (1991). We refer to such models as systems with extended equilibrium correction dynamics relative to the standard PCM and WECM models above.

Bårdsen and Nymoen (2003) show that extended equilibrium correction generally makes the wage-price process become dynamically stable also in the theoretical case where the rate of unemployment is exogenous and fixed.[7] As a corollary, we now state that if there is equilibrium correction in price setting , the restriction $\theta_w = 0$ no longer guarantees that the dynamic system has the properties of the PCM. Hence, even if there is a wage Phillips curve in the system, the expression for the natural rate of unemployment in (7) may not correspond to the true steady state implied by the extended equilibrium correction system. The reason is the presence of equilibrium correction in price setting, which adds extra stability to the system in a way that affects the mean rate of unemployment. In other words, with extended equilibrium correction, the natural rate is no longer determined by the parameters of the wage Phillips curve.

Extended equilibrium correction dynamics in wage- and price-setting models has a realistic ring to it, and the surveys of the literature in Kolsrud and Nymoen

[7] See also the analysis of the conditional wage-price system in Bårdsen et al. (2005, Ch. 6.4).

(1998) and Bårdsen and Nymoen (2003) indicate that there may have been an overemphasis on the differences in wage dynamics. Specifically, even if there is a well defined empirical wage Phillips curve in the US, it does not imply that $\mu_{u,PCM}$ defined by that Phillips curve is a relevant parameter for the US natural rate of unemployment. This is because there may be equilibrium correction elsewhere in the wage-price systems which dominate the wage Phillips curve, so that the implied mean of the rate of unemployment becomes a system property, more in line with $\mu_{u,WECM}$ above.

In the next section, where we consider an empirical PCM for the US economy, we will see an instance of how price setting equilibrium correction influences the behaviour of the system—and the rate of unemployment in particular.

3 Inflation-unemployment dynamics in the US

In this section we specify econometric models with different equations for wage dynamics, and investigate their impact on natural rate dynamics. Based on the discussion above, we expect to find that the specification of the wage equation has a large impact on the natural rate and its dynamics if there is little equilibrium correction elsewhere in the completing macroeconomic model. Conversely, with extended equilibrium correction in the system as a whole, the consequences of choosing between a Phillips curve and a wage equilibrium correction model are less important.

3.1 Data and empirical framework

Our operational measure of the rate of unemployment is the civilian unemployment rate, which is the commonly used unemployment variable in wage studies. The operational measure of the wage variable is the hourly manufacturing compensation rate, w_t, and productivity is defined as value added per hour worked, and is denoted z_t, see the Appendix for details. In parallel to the theoretical model, we also include an import price index in the data set, it is denoted pi_t. The theoretical section abstracted from the difference between 'consumer' and 'producer' prices. In the empirical model we include both a consumer price index, p_t , and a deflator of manufacturing value added, q_t. This affects the econometric specification of the two hypotheses of wage setting.

The Phillips curve model (PCM). In this case, the hypothesis A2 carries over directly, but notably for the producer real wage. Hence $w_t - q_t - z_t - \mu_w \sim \mathsf{I}(0)$, which is the same as claiming that the wage share is stationary; and $u_t - \mu_u \sim \mathsf{I}(0)$. The implied equilibrium correction dynamics is that Δw_t adjusts with respect to $u_{t-1} - \mu_u$, and that Δu_t adjusts with respect to $w_{t-1} - q_{t-1} - z_{t-1} - \mu_w$.

The wage equilibrium model (WECM). Workers' utility is linked to the consumer real wage, $w_t - p_t$, while firms care about the producer real wage, $w_t - q_t$. Theory nevertheless implies that, as long as unions have a strong bargaining power, the settled nominal wage will mainly reflect q_t and z_t. Empirical tests on data from the Scandinavian small open economies lend support to this view. For the US case, where unions are different in character and bargaining is more fragmented, a better hypothesis may be that the productivity corrected *consumer real wage* is stationary, hence $w_t - p_t - \iota z_t - \mu_w \sim \mathsf{I}(0)$, with $0 \leq \iota < 1$. The idea is that rather weak and uncoordinated unions manage to achieve a degree of compensation for increases in costs of living, but that workers only manage to extract a fraction of the productivity gains. Also in this case $u_t - \mu_u \sim \mathsf{I}(0)$, and in the equilibrium correction model, Δu_t adjusts with respect to $w_{t-1} - q_{t-1} - z_{t-1} - \mu_w$, but wage setting is different from the PCM case and Δw_t is assumed to adjust with respect to $w_{t-1} - p_{t-1} - \iota z_{t-1} - \mu_w$.

The empirical wage Phillips curve is well established on US data, so we start with this model. We first test the two PCM cointegration propositions, i.e., $w_t - q_t - z_t - \mu_w \sim \mathsf{I}(0)$ and $u_t - \mu_u \sim \mathsf{I}(0)$, and as a second step we specify a simultaneous equations model using the PCM equilibrium correcting mechanism as identifying restrictions. The methodology is discussed in detail in Bårdsen et al. (2005, Ch. 4-6).

3.2 An empirical PCM

Given the assumption of $\mathsf{I}(1)$-ness of wages, prices and productivity, logical consistency of the Phillips curve model of the natural rate requires that wages, producer prices and productivity are cointegrated. In this subsection we first show that cointegration is supported by formal tests, and second estimate a dynamic model which is an extension of the standard model of section 2.1.

3.2.1 Cointegration analysis

To test the null hypotheses of no cointegration, i.e., $w_t - q_t - z_t - \mu_w \sim \mathsf{I}(1)$ and $u_t - \mu_u \sim \mathsf{I}(1)$ we estimate a 2nd order VAR for the three endogenous variables w_t, q_t and u_t. The test is conditional on productivity, z_t.[8] The sample period is 1962-2004. Formally, the Johansen (1995) approach to cointegration analysis suggests one or two cointegrating vectors. Our interpretation of this result is that $w_t - q_t - z_t - \mu_w \sim \mathsf{I}(0)$ holds strongly in the data, while $u_t - \mu_u \sim \mathsf{I}(0)$ is a weaker empirical cointegrating relationship. On this basis the cointegration rank is set to 2, and we proceed to test the 4 implied over-identifying restrictions. The likelihood ratio test statistic is $\chi^2(4) = 5.75$, with a p-value of 0.22 showing that the PCM restrictions on the cointegrating vectors are statistically acceptable.

These conclusions are supported by Dickey-Fuller tests. For the rate of unemployment in particular, a 2nd order Dickey-Fuller regression, augmented by three dummies for structural breaks (namely ken_t, $oil_{1,t}$ and pow_t which are explained below) is a statistically adequate model for inference, following the principles of Andreou and Spanos (2003). The Dickey-Fuller statistics of this model, calculated sequentially over the period from 1975-2004 are never lower (in absolute value) than 2.5 and the average of the sequence is much higher. The end of sample value is 4.7. Although the exact critical value is unknown in this case (because of the inclusion of dummies), these values of the Dickey-Fuller statistic are highly suggestive that a formal test would reject the null hypothesis of a unit root.[9] The estimated

[8] The weak exogeneity of z_t may not hold in the data (in fact this would be an example of extended equilibrium correction), and in that case we loose statistical efficiency but this must be balanced against the gain in degrees of freedom.

[9] Already, Perron (1989) showed that the inclusion or omission of dummy variables is important for the outcome of unit root tests.

mean μ_u is also stable, using the 1961-1975 sample we obtain $\exp(\hat{\mu}_u) = 5.3\%$, and using the full sample 1962-2004 the estimated mean of the unemployment rate is $\exp(\hat{\mu}_u) = 5.6\%$. Hence, both the VAR cointegrating analysis and the Dickey-Fuller tests corroborate the validity of the modelling assumptions of $w_t - q_t - z_t - \mu_w \sim \mathsf{I}(0)$ and $u_t - \mu_u \sim \mathsf{I}(0)$ stated in section 2.

3.2.2 Econometric PCM model

The next stage is to specify and estimate a PCM, with the lagged wage share and the lagged unemployment rate included as equilibrium correction terms. At this point in the analysis, we first estimate an unrestricted equilibrium correction model, which we dub p-ecm and second we attempt to encompass the unrestricted system by an econometric model which has a wage Phillips curve as its core. This empirical model is an extension of the stylized model in equation (1)-(5) above. The notable extensions of the theoretical model are:

1. **Two price indices**: Since there are two domestic price indices, the econometric PCM contains equations for both Δq_t (producer prices) and Δp_t (consumption price index).

2. **Extended equilibrium correction:** The cointegration analysis of the system made up of w_t, q_t and u_t shows evidence of equilibrium correction of q_t with respect to the wage-share, so we expect to find such a relationship also in the simultaneous equations model. Moreover, since p_t was not included in the VAR, equilibrium correction behaviour in Δp_t may yet be revealed at this stage. Hence, the relationship in differences (3) in the standard PCM, is replaced by two equilibrium correction equations for Δq_t and Δp_t. Finally, equilibrium correction may affect Δz_t as well, in which case equation (4) in the standard model is replaced by an equilibrium correction equation.

3. **Structural breaks**: Variables representing shocks and intermittent structural breaks are included. First, we include a dummy (ken) which captures the Kennedy-Johnson administration policy to reduce unemployment. Second, there are two oil-price dummies, for 1974 and 1980 ($oil_{1,t}$ and $oil_{2,t}$) and in addition the annual rate of change of the oil price itself ($\Delta poil_t$) is an explanatory variable in the model. Third, a dummy representing periods of unusually high/low productivity growth, the 1990s in particular ($prod_t$). Fourth, a dummy (pow_t) representing the hypothesis that worker's ability to take benefit of the industrial prosperity was significantly lower in the 1990s than in earlier US booms. This hypothesis has been influential, also in the policy process. For example, Pollin (2002) argues that in the mid 1990s, the leadership of the Federal Reserve was convinced that the decline in bargaining power was a prime cause of the surprisingly low inflationary pressure.[10]

[10] See for example (Greenspan): `www.bog.frb.us.boarddocs/hh/1997/July/Testimony.htm`, and (Yellen, then member of the Fed Board of Governors): `http://www.federalreserve.gov/FOCM/Transcripts/1996/19960294Meeting.pdf`, p21.

Table 1: Diagnostics for VAR and identified econometric models.

	p-ecm	gen-ecm	Table 2 Identified PCM	Table 3 Identified WECM
$\hat{\sigma}_{\Delta w}$	0.78%	0.79%	0.59%	0.56%
$\hat{\sigma}_{\Delta u}$	8.64%	8.80%	8.14%	8.12%
$\hat{\sigma}_{\Delta p}$	0.67%	0.61%	0.62%	0.61%
$\hat{\sigma}_{\Delta z}$	1.17%	1.12%	1.15%	1.13%
$\hat{\sigma}_{\Delta q}$	1.70%	1.68%	2.28%	2.29%
$\mathsf{F}_{\mathsf{AR}(1-1)}$	0.72[0.81]	0.87[0.64]	0.87[0.65]	1.16[0.30]
$\chi^2_{\text{normality}}$	14.57[0.15]	20.62[0.02]	10.846[0.37]	22.5[0.01]
$\chi^2_{\text{enc,p-ecm}}$			50.316[0.38] 48 restrictions	
$\chi^2_{\text{enc,gen-ecm}}$			82.11[0.006] 53 restrictions	60.76[0.22] 53 restrictions

The numbers in [ ] are p-values. The sample is 1962-2004.

The p-ecm column of Table 1 shows the estimated standard errors (denoted $\hat{\sigma}_{\Delta w}$, $\hat{\sigma}_{\Delta u}$, $\hat{\sigma}_{\Delta p}$, $\hat{\sigma}_{\Delta q}$, $\hat{\sigma}_{\Delta z}$) of the 5 endogenous variables in the unrestricted equilibrium correction model. Below the estimated residual standard errors of each variable, the table shows two diagnostic tests based on the residual vector, for 1st order residual autocorrelation ($\mathsf{F}_{\mathsf{AR}(1-1)}$), and departure from normality ($\chi^2_{\text{normality}}$). The tests are vector versions of the well known single equation diagnostics, see Doornik and Hendry (2001a). The respective p-values are in brackets, and clearly we can proceed on the basis that the disturbances are normally distributed, and test relevant restrictions on the p-ecm, with the aim of obtaining an identified simultaneous equations PCM model.

The column labelled Table 2 shows diagnostics for the identified PCM, consisting of the estimated equations shown in Table 2 below. The model, estimated by FIML, corresponds to a set of restrictions on the p-ecm. Without any restrictions the model structure is unidentified, but the model in Table 2 is over-identified, and we are particularly interested in whether this model is a valid parsimonious representation of the p-ecm—i.e., whether it is an encompassing model. A natural test statistic is the likelihood ratio test of the over-identifying restrictions, see Hendry et al. (1988). This test statistic is denoted $\chi^2_{\text{enc,p-ecm}}$ in Table 1, and it shows that the 48 restrictions separating the unrestricted system from the identified PCM are jointly statistically acceptable, with a rather high p-value (columns 3 and 5 of Table 1 are relevant for the discussion of the bargaining model below).

The first equation is the wage Phillips curve. Augmentation is in terms of consumer price growth Δp_t, producer price growth Δq_t, and productivity in the form of the two year growth rate $\Delta_2 z_t$. The latter variable is consistent with the idea that it is the persistent productivity changes that lead to increased wage growth.[11] Note

[11] Staiger et al. (2002) report that without inclusion of productivty growth, their estimated real wage Phillips curve equations have unstable parameters. Our model is consistent with this

Table 2: The econometric PCM.

$$\Delta w_t = \underset{(0.0083)}{0.0229} + \underset{(0.0891)}{0.8855}\,\Delta p_t + \underset{(--)}{0.1145}\,\Delta q_t$$
$$+ \underset{(0.0408)}{0.3238}\,\Delta_2 z_t - \underset{(0.00859)}{0.02818}\,\Delta u_t - \underset{(0.00409)}{0.01731}\,u_{t-2}$$
$$- \underset{(0.00236)}{0.01188}\,\Delta^2 poil_t + \underset{(0.00689)}{0.0237}\,oil_{2,t} + \underset{(0.00286)}{0.0129}\,pow_t$$

$$\Delta u_t = \underset{(2.25)}{9.17} + \underset{(0.407)}{1.572}\,(w-q-z)_{t-1} - \underset{(0.0712)}{0.3565}\,u_{t-1} + \underset{(0.666)}{3.331}\,\Delta p_{t-1}$$
$$+ \underset{(0.12)}{0.2097}\,(p-pi)_{t-1} - \underset{(0.0426)}{0.1764}\,ken_t$$

$$\Delta p_t = \underset{(0.0108)}{0.02507} + \underset{(0.0636)}{0.6097}\,\Delta p_{t-1} + \underset{(0.0205)}{0.152}\,\Delta pi_t$$
$$+ \underset{(0.00523)}{0.01938}\,\Delta poil_t - \underset{(0.0102)}{0.02385}\,(p-pi)_{t-1} - \underset{(0.00777)}{0.01907}\,\Delta u_{t-1}$$
$$- \underset{(0.00572)}{0.009358}\,u_{t-1} - \underset{(0.00755)}{0.02462}\,oil_{1,t}$$

$$\Delta z_t = \underset{(0.283)}{0.6106} + \underset{(0.0515)}{0.1113}\,(w-q-z)_{t-1} + \underset{(0.00921)}{0.04003}\,\Delta u_{t-1} + \underset{(0.00745)}{0.02039}\,u_{t-2}$$
$$+ \underset{(0.0102)}{0.04525}\,(p-pi)_{t-1} + \underset{(0.00293)}{0.0123}\,prod_t$$

$$\Delta q_t = \underset{(0.54)}{1.089} + \underset{(0.0403)}{0.9744}\,\Delta(w-z)_t + \underset{(0.0982)}{0.1975}\,(w-q-z)_{t-1}$$
$$+ \underset{(---)}{0.02562}\,\Delta pi_t - \underset{(0.0169)}{0.06179}\,oil_{2,t}$$

Notes

The sample is 1962 to 2004. Estimation is by FIML.
Standard errors are in parentheses below the parameter estimates.
SeeTable 1 for residual standard errors, diagnostic tests, and encompassing tests.

that the vertical long run Phillips curve restriction is imposed, i.e., the coefficients of Δp_t and Δq_t sum to unity. Both the change in unemployment and the lagged rate u_{t-2} are significant at conventional levels of significance.

In addition to the conventional augmentation, the Phillips curve specification contains three variables representing the effects on wages of stochastic shocks and structural breaks: The stochastic shock is the double difference in oil prices, showing that oil price shocks wage growth. The OPEC-II oil price hike was of course special, and the positive and significant coefficient of $oil_{2,t}$ shows that there was a one-off compensation for that event. Finally, the estimation results confirm the hypothesis of low worker ability to push for higher wages in the 1990s: pow_t is a significant explanatory variable, and it is zero or negative for most of the last decade of the previous century—see the Appendix.

observation.

The second equation in Table 1 shows the empirical counterpart of equation (2) in the theoretical model. The lagged wage share $\beta_{u2}(w - q - z)_{t-1}$ appears strongly in the estimated equation with a coefficient of 1.57 for β_{u2}. The effect of the lagged unemployment rate is important for the stability of the system, and the fact that the coefficient corresponding to β_{u1} in equation (2) is found to be precisely estimated (with a value of -0.36) is thus corroborating the cointegration results in support of $u_t - \mu_u \sim \mathsf{I}(0)$ and $w_t - q_t - z_t - \mu_w \sim \mathsf{I}(0)$.

In addition to the crucial significance of $(w - q - z)_{t-1}$ in the unemployment equation, we identify a positive effect of the rate of lagged inflation, Δp_{t-1}, which we interpret as an effect of economic policy: higher inflation typically leads to a tightening of monetary policy and the rate of unemployment of course represents an important transmission mechanism. It is perhaps more surprising that we also estimate a positive effect of the lagged real exchange rate $(p - pi)_{t-1}$. Hence, despite the vastness of the domestic US economy, its rate of unemployment does not appear to be completely sheltered from sustained loss of international competitiveness.

In the theoretical PCM model, the third equation is a "consumer price equation" cast in differenced form, as explained above. In Table 2 there is a separate equilibrium correction model for Δp_t. It would represent a price Phillips curve if it was not from the inclusion of $(p - pi)_{t-1}$ albeit with a small coefficient (below, we will present robustness tests of its impact on the dynamic behaviour of the system). This is the first encounter of extended equilibrium correction dynamics.

There is evidence of other extensions of equilibrium correction in the two last equations of the model. Productivity Δz_t equilibrium corrects to the lagged wage share, corresponding to predictions from efficiency wage theories (it was assumed exogenous in the theoretical PCM model (1)-(5)), and it also depends on the lagged change and rate of unemployment. The last equation in Table 2 shows the estimated manufacturing producer price equation. As can be seen from the specification, Δq_t is simultaneously determined with Δw_t through the change in unit labour costs. There is a small effect of the change in import prices as well, but a quite large equilibrium correction coefficient with respect to the lagged wage share.

In sum, the empirical PCM contains the kind of extended equilibrium correction which, according to the analysis in section 2, may cause natural rate dynamics to behave significantly differently from the conventional Phillips curve dynamics. In section 4 we illustrate the dynamics of the empirical PCM by dynamic simulation. Before that, we consider whether an alternative to the wage Phillips curve can be formulated on this data set.

3.3 An empirical WECM

The previous sections showed that the two hypotheses of $w_t - q_t - z_t - \mu_w \sim \mathsf{I}(0)$ and $u_t - \mu_u \sim \mathsf{I}(0)$ are supported by cointegration analysis, and that a corresponding dynamic PCM with desirable statistical properties—for example encompassing the p-ecm—can be specified. Moreover, adding $(w - q - z - \mu_w)_{t-1}$ to the wage Phillips curve gives an insignificant coefficient (the 't-value' is 0.01). These findings are quite different from results on for example Scandinavian data, where the lagged wage share is typically found to be a significant equilibrium correction term in manufacturing sector wage equations, see e.g., Nymoen and Rødseth (2003).[12]

However, as explained in section 3.1, there are other possible equilibrium correction specifications to consider. For example with weak and poorly organized unions wages may be set by firms in the light of the reference wage ($\bar{w}_t$) and worker's probability of getting a job elsewhere. The job probability can be approximated by the unemployment rate, while at the aggregate level $\bar{w}_t$ is probably linked to the the general price level of the economy and to productivity. Hence we have the following alternative to $(w - q - z - \mu_w)_{t-1}$ as a predictor of Δw_t in an economy dominated by wage setting at the individual level or with weak unions:

$$w_t - p_t - \iota z_t - \lambda u_t - \mu_{wp} \sim \mathsf{I}(0), 0 \leq \iota < 1, \lambda \geq 0, \tag{10}$$

which can be viewed as a linear combination of the two $\mathsf{I}(0)$ variables $w_t - p_t - \iota z_t \sim \mathsf{I}(0)$ and $u_t \sim \mathsf{I}(0)$.

Analysis of a VAR consisting of w_t, p_t and z_t, keeping u_t as non-modelled, does not yield very strong results, but setting $\iota = 0.2$ and $\lambda = 0.1$ gives an equilibrium correction variable which at least has some stationary traits. Importantly, when the equilibrium correction variable is added to the unrestricted equilibrium correction system, to form a generalized unrestricted reduced form, gen-ecm, the PCM of Table 2 is no longer an encompassing model: the p-value of the encompassing test falls from 0.38 to 0.006, cf. the entry for $\chi^2_{\mathsf{enc,gen-ecm}}$ in the bottom row of Table 1. Hence, there is need for a different structural model to account of the force of $w_{t-1} - p_{t-1} - 0.2z_{t-1} + 0.1u_{t-1}$ in gen-ecm.

In terms of specification, the only difference between the econometric PCM and WECM is the wage equation. But in order to check how the point estimates of the coefficients of other equations in Table 2 are affected, all 5 of the WECM equations are reported in Table 3. The equilibrium correction wage equation includes $(w - p - 0.2z + 0.1u)_{t-1}$, and although the equilibrium correction coefficient is quite small numerically, its 't-value' is still significant (-5.9).

The coefficients of the other explanatory variables in the wage equation change very little compared to the PCM case, which indicates that the equilibrium correction term is relatively orthogonal with respect to the variables of the Phillips curve. The coefficient of the bargaining power dummy is an exception. The estimated coefficient halved, probably because the equilibrium correction term itself is related to bargaining power.[13] With the wage equation in place, the econometric WECM easily encompasses the gen-ecm, as shown by the value of $\chi^2_{\mathsf{enc,gen-ecm}}$ in the right column of Table 1. Direct inspection of the other structural equations confirms that their estimated coefficients change very little compared to the PCM case, hence any differences in the dynamic behaviour of the two models can be directly related to the different specifications of the wage equations.

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[12] In Bårdsen et al. (1998), the equilibrium correction framework is used to explain aggregate wage and price setting in Norway and the United Kingdom, with comparable and similar results for the two economies.

[13] The other main difference between the two wage equations is the presence of $\Delta^2 u_t$ in the WECM, but that difference is due to the specification of the error correction term, with u_{t-1} rather than u_{t-2} as table 2 would suggests.

Table 3: The econometric model with a wage equilibrium correction equation, WECM.

$$\Delta w_t = \underset{(0.0199)}{-\,0.1198} + \underset{(0.0665)}{0.8053}\,\Delta p_t + \underset{(--)}{0.1947}\,\Delta q_t$$
$$+ \underset{(0.0338)}{0.2955}\,\Delta_2 z_t - \underset{(0.0017)}{0.0094}\,\Delta^2 poil_t$$
$$+ \underset{(0.00607)}{0.02627}\,oil_{2,t} + \underset{(0.00219)}{0.006145}\,pow_t - \underset{(0.0048)}{0.02229}\,\Delta^2 u_t$$
$$- \underset{(0.012)}{0.0712}\,(w - p - 0.2z + 0.1u)_{t-1}$$

$$\Delta u_t = \underset{(2.23)}{8.951} - \underset{(0.0429)}{0.1721}\,ken_t - \underset{(0.072)}{0.3456}\,u_{t-1}$$
$$+ \underset{(0.673)}{3.369}\,\Delta p_{t-1} + \underset{(0.404)}{1.537}\,(w - q - z)_{t-1} + \underset{(0.121)}{0.2097}\,(p - pi)_{t-1}$$

$$\Delta p_t = \underset{(0.0106)}{0.02443} + \underset{(0.0637)}{0.6231}\,\Delta p_{t-1} + \underset{(0.0211)}{0.1594}\,\Delta pi_t$$
$$+ \underset{(0.00533)}{0.0177}\,\Delta poil_t - \underset{(0.0103)}{0.02021}\,(p - pi)_{t-1} - \underset{(0.00785)}{0.02366}\,\Delta u_{t-1}$$
$$- \underset{(0.00556)}{0.00918}\,u_{t-1} - \underset{(0.00778)}{0.02721}\,oil_{1,t}$$

$$\Delta z_t = \underset{(0.28)}{0.6404} + \underset{(0.051)}{0.1173}\,(w - q - z)_{t-1} + \underset{(0.00906)}{0.04593}\,(p - pi)_{t-1}$$
$$+ \underset{(0.00933)}{0.04517}\,\Delta u_{t-1} + \underset{(0.00625)}{0.0223}\,u_{t-2} + \underset{(0.00253)}{0.01221}\,prod_t$$

$$\Delta q_t = \underset{(0.495)}{1.016} + \underset{(0.0319)}{0.9664}\,\Delta(w - z)_t + \underset{(0.0901)}{0.1843}\,(w - q - z)_{t-1}$$
$$+ \underset{(--)}{0.03361}\,\Delta pi_t - \underset{(0.0168)}{0.06224}\,oil_{2,t}$$

Notes

See Table 2

4 Natural rate dynamics

The last section discussed two dynamic models of the US natural rate. The only difference between the two models is the specification of the wage equation. It is a wage Phillips curve in the PCM in Table 2, and an equilibrium correction wage equation in the model in Table 3. According to a view shared by most economists, this difference is essential and should have important implications for the dynamics of the equilibrium wage, see Blanchard and Katz (1999).

However, we have hypothesized that extended equilibrium correction may come to dominate unemployment dynamics even though the structural wage equation is a Phillips curve. In this section we illustrate the empirical relevance of these ideas using the estimation results of the previous section.

The PCM and WECM solutions for wage growth and unemployment are easily found by dynamic simulation of the two models in Table 2 (PCM) and Table 3

(WECM). Figure 1, panel a) and b) show the solution for Δw_t and u_t in the WECM. The model's solution is seen to fit the data rather well well. For Δw_t some of the good fit at the end of the period is of course due to inclusion of the two dummies: pow_t because it is an explanatory variable in the wage equation itself, and $prod_t$ because that dummy helps keep the solution for Δz_t on track, and productivity growth in turn affects wages in the model, as we have seen.

The solution for the rate of unemployment shown in panel b) tracks the reduction in actual unemployment to 3.5%, corresponding to 1.25 on the log scale of panel b). This is mainly due to the ken_t dummy variable in the model. The solution also tracks the tendency in the unemployment changes in the period from the mid 1970s to the late 1980s. For the last 15 years of the period, the solution for the unemployment rate is relatively constant though. The "lack of fit" in the 1990s is however not a sign of model failure, but reflects that by starting the simulation in 1962 the simulated values for 1990-2004 are quite close to the model's steady state.[14] According to the model, the explanatory variables with most influence on the steady state, are the bargaining and power productivity dummies, pow_t and $prod_t$, though these two variables affect the solution for the rate of unemployment only indirectly, through their effect on the solution for the wage-share. The solution in panel b), therefore shows that the two main structural breaks during the last 15 years of the sample have affected the steady state rate of unemployment rather weakly.

Having looked at the solution of the WECM, we next turn to the differences between the solution of that model and of the PCM. As explained above, the consensus view is that the difference is likely to be large, because there is fundamental differences in wage setting in the two models. However, panel c) and d) of Figure 1, showing the scatter plots of the simulated values of Δw_t and u_t of the two models, tell a different story: the solutions of the PCM and the WECM are nearly identical. However, this paradox is resolved by remembering the appearance of extended equilibrium correction effects in the two models, which dominates the effects of the different specifications of the wage equation.

In order to specify a PCM which behaves distinctively different from the WECM, and more in line with the textbook case of a vertical long run Phillips curve, the equilibrating mechanisms of the model must be restricted much more than in Table 2. Hence we consider a *restricted* econometric PCM which corresponds to the theoretical PCM of section 2.1, where there are no extended equilibrium correction in the Δp_t or Δz_t equations. Therefore, in the restricted PCM, the coefficients of $p_{t-1} - pi_{t-1}$ in the Δp_t and Δz_t equations are set to zero, along with for example the coefficient of the lagged wage share in the Δq_t equation. It should come as no surprise to find that these additional restrictions are statistically rejected, with a value of the test statistic $\chi^2_{\mathsf{enc,p-ecm}} = 128$ (cf. Table 1), which is highly significant with 57 degrees of freedom. Hence, unlike the econometric PCM and WECM, which encompass their respective unrestricted equilibrium correction systems, the restricted PCM is firmly rejected by the statistical tests.

Figure 2 shows how the three different models respond to a permanent and

[14]This is confirmed by starting the simulation 10 years later, in 1974. For Δw_t and u_t in particular, the solution of the 1990's is not much affected. There are some large roots in the solution though. In the WEM the non trival roots are 0.98, 0.94, 0.8 and 0.7 (a complex pair) and in the PCM: 0.94, 0.79, 0.67 and 0.31 (a complex pair).

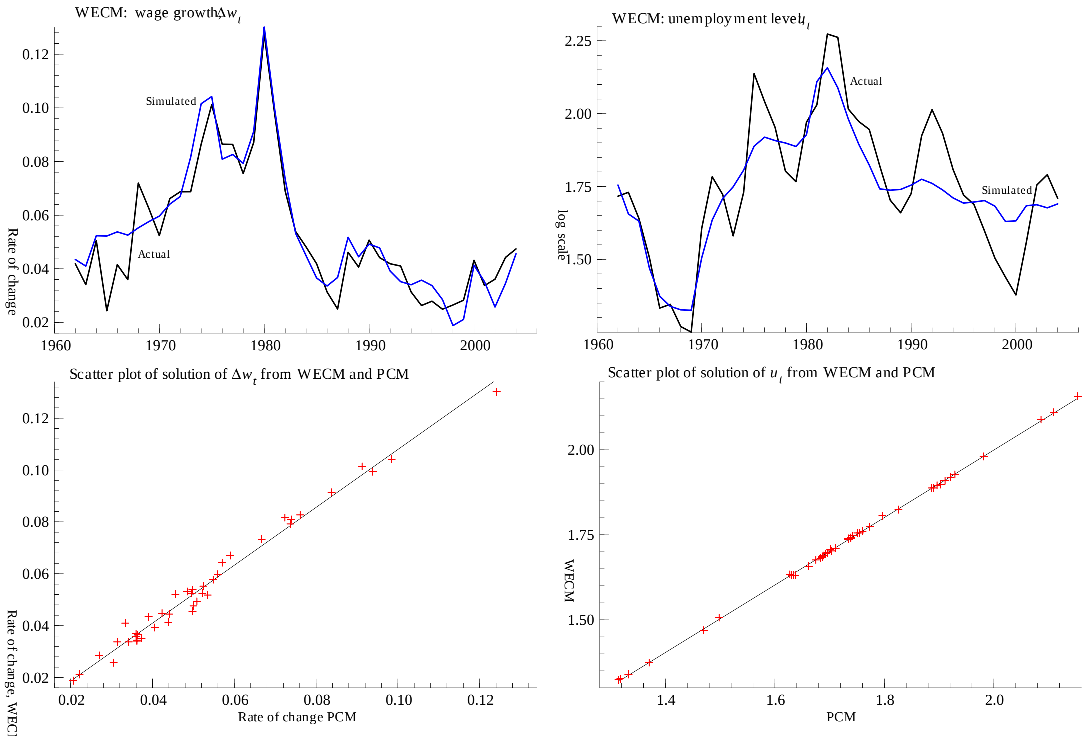

Figure 1: Dynamic simulation of the WECM and PCM for the period 1962-2004. Panel a) shows the WECM solution for Δw_t together with the actual value, and panel b) is the same graph for u_t. Panel c) shows the scatter plot of the simulated Δw_t values of the WECM and PCM models, with regression line drawn. Panel d) shows the similar graph for the rate of unemployment.

exogenous shock to unemployment. Thus we consider a counterfactual experiment which corresponds to a reduction in the parameter β_{u0} in equation (**??**) of the theory model. The shock has been calibrated to correspond to a reduction from 5% to 4.5% in the unemployment rate. In Figure 2, panel a), the graph for the econometric PCM shows the most vigorous wage response, corresponding to a lowering of the annual rate from 5% to 4.4% in the third year after the shock. There is less marked difference between the responses of the WECM and the PCM in panel b), which shows the inflation response, which is due to the direct effect of the rate of unemployment in the Δp_t equation of both models.

The differences between the three models are also apparent in panels c) and d), showing the cumulated multipliers for unemployment and in the wage share. For the WECM and the PCM, there is a sharp and lasting increase in the rate of unemployment. This kind of response cannot be reconciled with the stylized Phillips curve model of section 2.1, which only allows shocks that arise in the Phillips curve equation to affect the steady state unemployment rate—cf. that the parameter β_{u0} that we have increased in the experiment does not appear in the expression for the theoretical PCM steady state unemployment rate in equation (7). Nevertheless, the responses in Figure 2 happen for perfectly logical reasons since the *econometric* WECM and PCM are in fact quite similar due to extended equilibrium correction.

The graph for the restricted econometric PCM in panel c) shows the response

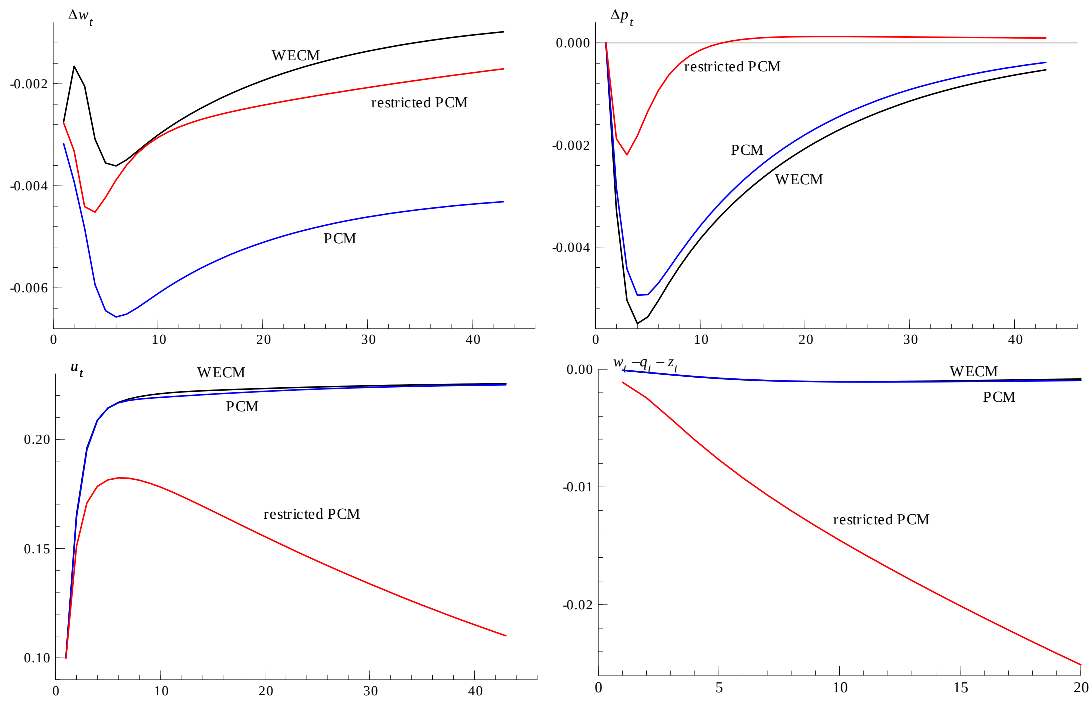

Figure 2: Dynamic multipliers of the econometric models PCM, WECM, and the restricted PCM , to a permanent exogenous 0.5 reduction in the unemployment percentage.

pattern that correspond to the model of section 2.1, and of the theoretical PCM steady state unemployment rate in equation (7) of the vertical Phillips curve. Since the steady state unemployment rate of this specification of the model only depends on the parameters of the wage Phillips curve, the shock to the unemployment rate has to be reversed completely before a new equilibrium can be restored. The single equilibrating mechanism of the model is the response of Δu_t to the lagged wage share, which therefore has to fall to a new steady state level. As can be seen in panels c) and d), the speed of adjustment is very low. For practical purposes it is as if the level of unemployment never returns to its initial and natural value. Thus, in the *restricted* PCM, corresponding to the standard natural rate Phillips curve model of section 2.1, the single equilibrating mechanism is extremely weak, making stationarity of u_t more of a formality than an important system property.

5 Stability of the natural rate

Frisch (1936) anticipated the day when it would become common among economists to define (and measure) 'normal' or natural values of economic variables by the values of the variables in a stationary state. As pointed out above, there has been little development in that direction in the estimation of the natural rate of unemployment. The dominant strategy has been to estimate the natural rate from partial models, as in the case of the wage Phillips curve. While econometrically sophisticated, as in Staiger et al. (1997), these studies do not address the important issue of dynamic stability of the rate of unemployment around the estimated natural rate. Moreover, completely *ad hoc* methods for measuring the natural rate have also gained currency, see e.g., Holden and Nymoen (2002) for an appreciation of one of the OECD's methods.

As pointed out by Fair (2005), part of the explanation for the slow progress in the direction that Frisch foresaw lies in the low confidence in the steady-state properties of estimated macroeconometric models. In this paper we have illustrated at least one feature of econometric models of the natural rate of unemployment which is crucial for the evaluation of steady-state properties, namely the specification of equilibrium correction mechanisms. We regard this mainly as a methodological contribution, and the detailed specification of the models can of course be contested. We do believe, however, that the main picture of extended equilibrium correction dominating the standard Phillips curve will prove to be a robust feature.

In none of the models considered above is the natural rate a completely constant and invariant entity. However, there is a difference between our framework and the *time varying NAIRU* model of Gordon (1997). In the time varying natural rate model, *all* shocks, small and large, influence the estimated natural rate. However, small and random shocks, by their very nature, either vanish or are counter-acted by other shocks, usually after only a short while. Thus, a method which feeds such disturbances into the estimated natural rate may induce too much volatility in the estimated natural rate. It is a different matter with intermittent and large shocks, and with events which are usually recognized as important in contemporary economic analysis and debate. Our modelling framework allows such structural changes to affect the estimated natural rate.

As we have seen, the empirical PCM and the WECM, but not the *restricted* PCM, appears to dynamically stable. On this basis, following Frisch's suggestion, we may interpret the values obtained by dynamic simulation, as reasonably good approximations to the models' implied natural rate, for example $\mu_{u,WECM}$ in the notation of section 2.

However, there is still the issue about the credibility of using simulated values to represent the natural rate. For one thing, even if one accepts our method in principle, there is a question whether the simulated values actually correspond to the steady state or whether they are influenced by the initial conditions, or by other factors which should not, by our definition, influence the natural rate. Above we showed that the initial conditions do not have much impact on the simulated values in Figure 1, panel b). However, the simulated values of other variables of the model may nevertheless have an influence on the solution of the rate of unemployment in the 1989-2004 period.

In order to check the robustness of the model solution *qua* natural rate we have calculated a natural rate estimate based on the semi-reduced form for the rate of unemployment. The resulting estimated equation is similar to the augmented Dickey-Fuller regression of section 3.2.1, but with the lagged values of the wage share and the real exchange rate as additional variables. The natural rate estimate of this model is obtained by setting the explanatory variables equal to their average values. In this way, we 'cut off' the link between the reduced form of the rate of

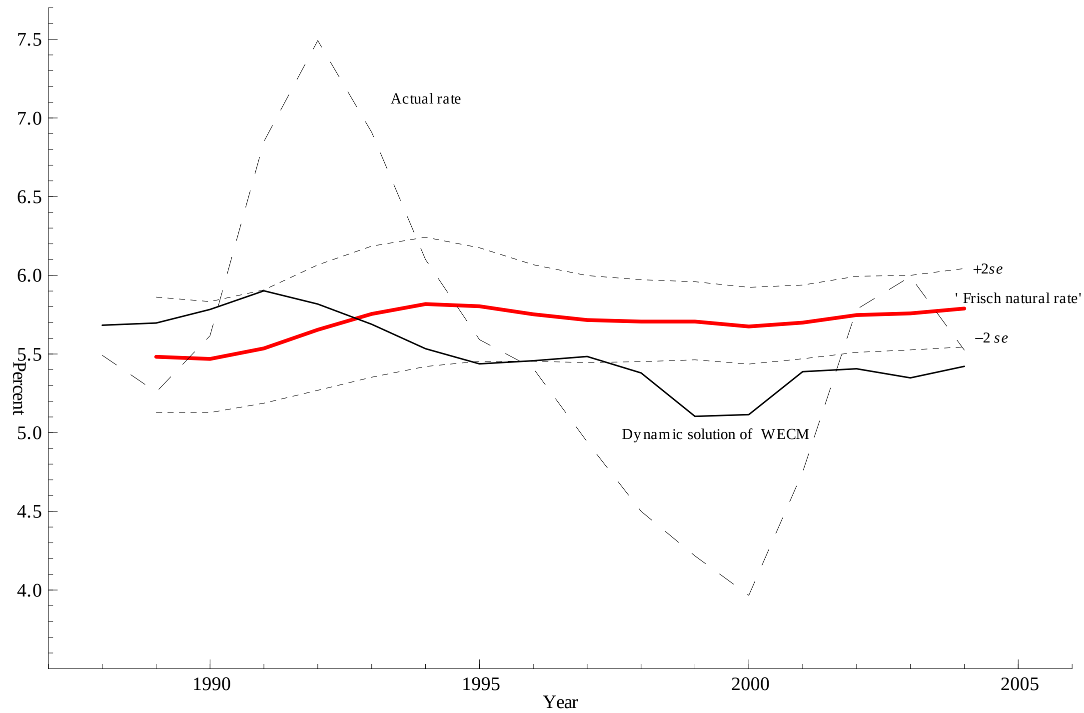

Figure 3: The civilian unemployment rate together with two measures of the natural unemployment rate: the solution of the estimated WECM, see panel b) of figure 1, and the mean unemployment rate from a semi-reduced form from WECM, with ± 2 standard errors, denoted $\pm 2se$ in the graph.

unemployment and the rest of the model.[15]

Figure 3 shows the actual rate of unemployment as the dotted line. The estimate from the semi-reduced form, denoted *'Frisch natural rate'* in the graphs, is shown as a thick line, and we have added the associated 95% confidence interval of the mean, denoted as $\pm 2se$ in the graph. The *'Frisch natural rate'* has been estimated recursively, hence the starting point of the lines are based on the 29 observations from 1961 to 1989. The end-point of the curve shows the results for the full sample from 1961 to 2004. The impression is that this estimate is very stable over the 16 year period from 1989-2004. Figure 3 also shows the simulated values of WECM, i.e., the same solution as shown in Figure 1 (panel b), but transformed to percentages. As argued above, due to asymptotic stability of the model, these simulated values approximate the implied natural rate of the full model, $\hat{\mu}_{u,WECM}$.

As explained above, the estimated WECM includes two of the most cited candidates for a reduction of the 'natural rate' in the 1990s: the reduction of workers' bargaining power and the unusually high productivity growth. The two factors have statistically and numerically significant effects on wage growth in our estimated model, and logically they are part of the explanation why the line for the dynamic solution of WECM lies below the line of *'Frisch natural rate'* after 1993. The highest

[15]This can be seen as a variant of the procedure proposed in Frisch (1936), as an alternative to the full steady state, for estimation of natural values of variables by modifying structural macroeconomic models, see Fair (2005).

$\hat{\mu}_{u,WECM}$ is 5.9% (in 1991), and the lowest is 5.1% (in 1999). This is however a smaller estimated reduction in the natural rate than the best evidence based on estimation of Phillips curves, Staiger et al. (2002), which suggests a 1.5 percentage point reduction between 1992 and 2000. Moreover, while the graphs of Staiger et al. (2002) indicate a continued fall in the natural rate also after 2002, our estimate suggests that the natural rate might have been stabilized in the course of the period 2000-2004.

6 Conclusions

This paper has discussed methodological and substantive issues relating to the empirical assessment of the US natural rate, starting by noting that the methodology underlying the consensus view is based on a highly restrictive model of wages, prices and the rate of unemployment, dubbed PCM above. Another model, called WECM, with equilibrium correction in wage setting is an alternative hypothesis to the wage Phillips curve. The consensus view is that the PCM and WECM are polar cases, but we show that this is only true if one abstracts from equilibrium correction behaviour elsewhere in the system, in price setting in particular. We dub this system feature extended equilibrium correction. Thus, even if the wage Phillips curve is the preferred model of US wage dynamics, it does not follow that the natural rate can be estimated from the empirical wage Phillips curve alone. Due to extended equilibrium correction, the PCM dynamics might become almost indistinguishable from the dynamics of the WECM. Our econometric versions of PCM and WECM confirm this feature, and only in the case where we tailor the PCM dynamics by imposing restriction that are rejected by statistical tests, do the dynamics correspond to the standard analysis.

It is a widely held view that differences in wage dynamics between the USA and Europe go a long way towards explaining the different behaviour of the unemployment rates on the two sides of the Atlantic. Hence research has focused on the specification of wage equations. One belief shared by a majority of economists is that the relatively swift adjustment of the US unemployment rate, and its apparent insulation from shocks originating in demand sector of the economy, is due to supply side behaviour which is represented by a wage Phillips curve. While not wanting to downplay the importance of wage dynamics for the comparative macroeconomic performance of different economies, our results show that the wage Phillips curve and the error correcting wage equation may not be the polar cases that the standard framework will have us believe. In our analysis, equilibrium correction elsewhere in the system may be (almost) as important for natural rate dynamics as wage setting dynamics. Thus, the comparative stability of the US natural rate may be less of a Phillips curve property, and more of a system property than the conventional analysis suggests. Specifically, the natural rate may have stayed constant because demand shocks have had a tendency to disappear in this vast economy, sometimes with the aid of good economic policies. Unlike the incumbent model of the US natural rate, our empirical results do not rule out the possibility that a sufficiently large and persistent demand shock, may have long lasting effects on US unemployment.

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A Data definitions

Economic time series

A main data source has been the AMECO (Annual Macro-Economic) database of the European Commisions's Directorate General for Economic and Financial Affairs (DG ECFIN). The other main sources are EcoWin and Economagic.

W_t- Compensation of employees, manufacturing industry, nominal USD. AMECO code: HMCMW. The AMECO series was spliced by the Bureau of Labor Statistics Employment cost index, manufacturing, private industry. Source: Economagic.

P_t- Consumer price index. 1995=100. AMECO code ZCPIN.

Q_t- Price deflator of gross value added, manufacturing industry, 1995=100. AMECO code PVGM.

Z_t- Labour productivity, output per hours worked, manufacturing. EcoWin code ew:usa09102

PI_t- Price deflator on imports of goods and services. 1995=100. AMECO code PMGS.

U_t- Unemployment rate, in percent. Civilian unemployment, Source: Economagic, St.Louis Fed.

$POIL_t-$ Price of West Texas Intermediate Crude, USD Per Barrel. Source: Economagic

As explained in the text, lower case letter refer to the logarithm of the original variables above, $u_t = \log(U_t)$ for example.

Dummies.

pow_t- Bargaining power dummy, see section 3.2 for motivation. It is 1 in 1962 and 1964; -0.5 in 1995; -1 in 1996 and 1997; -0.5 in the years 1998-2001; and -0.5 in 2003. Otherwise zero.

$prod_t-$ Dummy for unanticipated high or low productivity growth. It is -1 in 1974, 1979, 1980 and 1989; and 1 in the period 1995-2003.

$oil_{1t}-$ 1 in 1974, otherwise zero.

$oil_{2t}-$ 1 in 1980, otherwise zero.
ken_t- 1 Kennedy-Johnson dummy, 1 in the period 1965-1969, zero elsewhere.