The Econometrics of Macroeconomic Modelling

GUNNAR BÅRDSEN
ØYVIND EITRHEIM
EILEV S. JANSEN
AND
RAGNAR NYMOEN

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The New Keynesian Phillips curve

Hitherto, we have considered models that have a unique backward solution, given a set of initial conditions. Even though individual variables may be dominated by unit roots, models defined in terms of differences and cointegration relationships are also asymptotically stable. Models with forward-looking expectations are not contained by this framework. Recently a coherent theory of price-setting with rational expectations has gained in popularity. In this chapter, we give an appraisal of the New Keynesian Phillips curve model (hereafter NPCM) as an empirical model of inflation. The favourable evidence for NPCMs on Euro-area data reported in earlier studies is illusive. The empirical support for the economic forcing variable is fragile, and little distinguishes the performance of the estimated NPCM from a pure time-series model of the inflation rate. The NPCM can be reinterpreted as a highly restricted (and therefore unlikely) equilibrium correction model. Using that framework, we construct tests based on variable addition and encompassing. The results show that economists should not accept the NPCM too readily, and that specific hypotheses about expectations terms are better handled as potential extensions of existing econometrically adequate models.

7.1 Introduction

The previous four chapters have analysed alternative models of wage–price setting in small open economies. A common underlying assumption has been that all processes are causal or future independent processes, that is, the roots of the characteristic polynomials are on (unit roots) or inside the unit circle. This means that the model can be solved uniquely from known initial conditions. In this chapter, we turn to rational expectations models—systems where expected future values of endogenous variables enter as explanatory variables, in one or more equations. Rational expectations models yield different types of solutions than causal models. In principle, a solution depends on (all) future values of the model's disturbances. However, if some of the characteristic roots have modulus less than unity while the others have modulus bigger than unity, saddle-path solutions may exist. Saddle-path solutions are not asymptotically stable but depend on very specific initial conditions. Assume that the system is initially in a stationary situation A. If a shock occurs that defines a new stationary situation B, there are no stable dynamic trajectories starting from A, due to the lack of asymptotic dynamic stability. The endogenous variables of a macroeconomic model can be classified as state or jump variables. The time derivatives of state variables are always finite. In contrast, and as the name suggests, jump variables can shift up or down to new levels quite instantaneously (exchange rates and other asset prices are common examples). Jump variables play a key role in saddle-path equilibria. Essentially, if a shock occurs in a stationary situation A, instability is avoided by one or more jump variables jumping instantaneously to establish a new set of initial conditions that set the dynamics on to the saddle path leading to the new stationary situation B. Models with saddle-path solutions are important in academic macroeconomics, as demonstrated by, for example, the monetary theory of the exchange rate and Dornbusch's (1976) overshooting model. Whether saddle-path equilibria have a role in econometric models of inflation is a separate issue, which we address by considering the New Keynesian Phillips curve.

The New Keynesian Phillips Curve Model (NPCM) is aspiring to become the new consensus theory of inflation in modern monetary economics. This position is due to its stringent theoretical derivation, as laid out in Clarida *et al.* (1999), Svensson (2000), and Woodford (2003: ch. 3). In addition, empirical evidence is accumulating rapidly. For example, the recent studies of Galí and Gertler (1999) and Galí *et al.* (2001), hereafter GG and GGL, claim to have found considerable empirical support for the NPCM—using European as well as United States data. Moreover, Batini *et al.* (2000) derives an open economy NPCM which they have on United Kingdom data with supportive results for the specification. In this chapter, we re-analyse the data used in two of these studies, namely GGL and the study by Batini *et al.* (2000). The results show that the empirical relevance of the NPCM on these data sets is very weak. We reach this surprising conclusion by applying encompassing tests, where the NPCM is tested against earlier econometric inflation models, as opposed to the corroborative approach of the NPCM papers. In addition we also examine the relevance of the NPCM for Norwegian inflation.[1]

The structure of the chapter is as follows. After defining the model in Section 7.2, we investigate the dynamic properties of the NPCM in Section 7.3. This entails not only the NPCM equation, but also specification of a process

[1] This chapter draws on Bårdsen *et al.* (2002*b*, 2004).

for the forcing variable. Given that a system of linear difference equations is the right framework for theoretical discussions about stability and the type of solution (forward or backward), it follows that the practice of deciding on these issues on the basis of single equation estimation is not robust to extensions of the information set. For example, a forward solution may suggest itself from estimation of the NPCM equation alone, while system estimation may show that the forcing variable is endogenous, giving rise to a different set of characteristic roots and potentially giving support to a backward solution.

Section 7.4 discusses estimation issues of the NPCM, using Euro-area data for illustration. After conducting a sensitivity analysis of estimates of the model under the assumption of correct specification, we apply several methods for testing and evaluating the specification in Section 7.5. We conclude that the specification is not robust. In particular, building on the insight from Section 7.3, we show that it is useful to extend the evaluation from the single equation NPCM to a system consisting of the rate of inflation and the forcing variable.

Another strategy of model evaluation is to consider competing theories, resulting in alternative model specifications. For example, there are several studies that have found support for incomplete competition models, giving rise to systems with cointegrating relationships between wages, prices, unemployment, and productivity, as well a certain ordering of causality. In Section 7.5.4 we show that these existing results can be used to test the encompassing implications of the NPCM. This approach is applied to the open economy version of the NPCM of Batini *et al.* (2000). Finally we add to the existing evidence by evaluating the NPCM on Norwegian data and testing the encompassing implications. Appendix A.2 provides the necessary background material on solution and estimation of rational expectations models.

7.2 The NPCM defined

Let p_t be the log of a price level index. The NPCM states that inflation, defined as $\Delta p_t \equiv p_t - p_{t-1}$, is explained by $\mathsf{E}_t \Delta p_{t+1}$, expected inflation one period ahead conditional upon information available at time t, and excess demand or marginal costs x_t (e.g. output gap, the unemployment rate, or the wage share in logs):

$$\Delta p_t = b_{p_1} \mathsf{E}_t \Delta p_{t+1} + b_{p2} x_t + \varepsilon_{pt}, \tag{7.1}$$

where ε_{pt} is a stochastic error term. Roberts (1995) shows that several New Keynesian models with rational expectations have (7.1) as a common representation—including the models of staggered contracts developed by Taylor (1979*b*, 1980)[2] and Calvo (1983), and the quadratic price adjustment cost model of Rotemberg (1982). GG gives a formulation of the NPCM in line with Calvo's

[2] The overlapping wage contract model of sticky prices is also attributed to Phelps (1978).

work: they assume that a firm takes account of the expected future path of nominal marginal costs when setting its price, given the likelihood that its price may remain fixed for multiple periods. This leads to a version of the inflation equation (7.1), where the forcing variable x_t is the representative firm's real marginal costs (measured as deviations from its steady-state value). They argue that the wage share (the labour income share) ws_t is a plausible indicator for the average real marginal costs, which they use in the empirical analysis. The alternative, hybrid version of the NPCM that uses both $\mathsf{E}_t \Delta p_{t+1}$ and lagged inflation as explanatory variables is also discussed later.

7.3 NPCM as a system

Equation (7.1) is incomplete as a model for inflation, since the status of x_t is left unspecified. On the one hand, the use of the term forcing variable, suggests exogeneity, whereas the custom of instrumenting the variable in estimation is germane to endogeneity. In order to make progress, we therefore consider the following completing system of stochastic linear difference equations[3]

$$\Delta p_t = b_{p1} \Delta p_{t+1} + b_{p2} x_t + \varepsilon_{pt} - b_{p1} \eta_{t+1}, \tag{7.2}$$

$$x_t = b_{x1} \Delta p_{t-1} + b_{x2} x_{t-1} + \varepsilon_{xt}, \qquad 0 \leq |b_{x2}| < 1. \tag{7.3}$$

The first equation is adapted from (7.1), utilising that $\mathsf{E}_t \Delta p_{t+1} = \Delta p_{t+1} - \eta_{t+1}$, where η_{t+1} is the expectation error. Equation (7.3) captures that there may be feedback from inflation on the forcing variable x_t (output-gap, the rate of unemployment or the wage share) in which case $b_{x1} \neq 0$.

In order to discuss the dynamic properties of this system, re-arrange (7.2) to yield

$$\Delta p_{t+1} = \frac{1}{b_{p1}} \Delta p_t - \frac{b_{p2}}{b_{p1}} x_t - \frac{1}{b_{p1}} \varepsilon_{pt} + \eta_{t+1} \tag{7.4}$$

and substitute x_t with the right-hand side of equation (7.3). The characteristic polynomial for the system (7.3) and (7.4) is

$$p(\lambda) = \lambda^2 - \left[\frac{1}{b_{p1}} + b_{x2} \right] \lambda + \frac{1}{b_{p1}} [b_{p2} b_{x1} + b_{x2}]. \tag{7.5}$$

If neither of the two roots is on the unit circle, unique asymptotically stationary solutions exist. They may be either causal solutions (functions of past values of the disturbances and of initial conditions) or future dependent solutions (functions of future values of the disturbances and of terminal conditions), see Brockwell and Davies (1991: ch. 3) and Gourieroux and Monfort (1997: ch. 12).

The future dependent solution is a hallmark of the NPC. Consider for example the case of $b_{x1} = 0$, so that x_t is a strongly exogenous forcing variable in the NPCM. This restriction gives the two roots $\lambda_1 = b_{p1}^{-1}$ and $\lambda_2 = b_{x2}$.

[3] Constant terms are omitted for ease of exposition.

Given the restriction on b_{x2} in (7.3), the second root is always less than one, meaning that x_t is a causal process that can be determined from the backward solution. However, since $\lambda_1 = b_{p1}^{-1}$ there are three possibilities for Δp_t: (1) No stationary solution: $b_{p1} = 1$; (2) A causal solution: $b_{p1} > 1$; (3) A future dependent solution: $b_{p1} < 1$. If $b_{x1} \neq 0$, a stationary solution may exist even in the case of $b_{p1} = 1$. This is due to the multiplicative term $b_{p2}b_{x1}$ in (7.5). The economic interpretation of the term is the possibility of stabilising interaction between price-setting and product (or labour) markets—as in the case of a conventional Phillips curve.

As a numerical example, consider the set of coefficient values: $b_{p1} = 1$, $b_{p2} = 0.05$, $b_{x2} = 0.7$, and $b_{x1} = 0.2$, corresponding to x_t (interpreted as the output-gap) influencing Δp_t positively, and the lagged rate of inflation having a positive coefficient in the equation for x_t. The roots of (7.5) are in this case $\{0.96, 0.74\}$, so there is a causal solution. However, if $b_{x1} < 0$, there is a future dependent solution since then the largest root is greater than one.

Finding that the existence and nature of a stationary solution is a system property is of course trivial. Nevertheless, many empirical studies only model the Phillips curve, leaving the x_t part of the system implicit. This is unfortunate, since the same studies often invoke a solution of the well-known form[4]

$$\Delta p_t = \left(\frac{b_{p2}}{1 - b_{p1}b_{x2}} \right) x_t + \varepsilon_{pt}. \tag{7.6}$$

Clearly, (7.6) hinges on $b_{p1}b_{x2} < 1$ which involves the coefficient b_{x2} of the x_t process.

If we consider the rate of inflation to be a jump variable, there may be a saddle-path equilibrium as suggested by the phase diagram in Figure 7.1. The drawing is based on $b_{p2} < 0$, so we now interpret x_t as the rate of unemployment. The line representing combinations of Δp_t and x_t consistent with $\Delta^2 p_t = 0$ is downward sloping. The set of pairs $\{\Delta p_t,\ x_t\}$ consistent with $\Delta x_t = 0$ are represented by the thick vertical line (this is due to $b_{x1} = 0$ as above). Point a is a stationary situation, but it is not asymptotically stable. Suppose that there is a rise in x represented by a rightward shift in the vertical curve, which is drawn with a thinner line. The arrows show a potential unstable trajectory towards the north-east away from the initial equilibrium. However, if we consider Δp_t to be a jump variable and x_t as state variable, the rate of inflation may jump to a point such as b and thereafter move gradually along the saddle path connecting b and the new stationary state c.

The jump behaviour implied by models with forward expected inflation is at odds with observed behaviour of inflation. This has led several authors to suggest a 'hybrid' model, by heuristically assuming the existence of both forward- and backward-looking agents; see, for example, Fuhrer and Moore (1995). Also Chadha *et al.* (1992) suggest a form of wage-setting behaviour that would

[4] That is, subject to the transversality condition $\lim_{n\to\infty}(b_{p1})^{n+1}\Delta p_{t+n+1} = 0$.

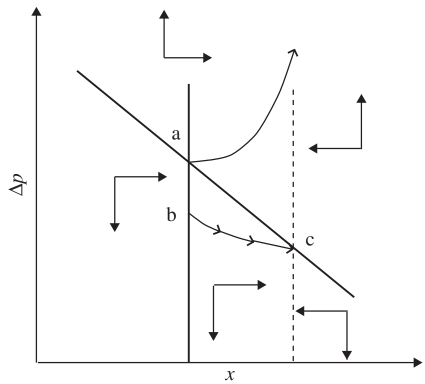

Figure 7.1. Phase diagram for the system for the case of $b_{p1} < 1$, $b_{p2} < 0$, and $b_{x1} = 0$

lead to some inflation stickiness and to inflation being a weighted average of both past inflation and expected future inflation. Fuhrer (1997) examines such a model empirically and finds that future prices are empirically unimportant in explaining price and inflation behaviour compared to past prices.

In the same spirit as these authors, and with particular reference to the empirical assessment in Fuhrer (1997), GG also derive a hybrid Phillips curve that allows a subset of firms to have a backward-looking rule to set prices. The hybrid model contains the wage share as the driving variable and thus nests their version of the NPCM as a special case. This amounts to the specification

$$\Delta p_t = b^f_{p1} \mathsf{E}_t \Delta p_{t+1} + b^b_{p1} \Delta p_{t-1} + b_{p2} x_t + \varepsilon_{pt}. \tag{7.7}$$

Galí and Gertler (1999) estimate (7.7) for the United States in several variants—using different inflation measures, different normalisation rules for the GMM estimation, including additional lags of inflations in the equation and splitting the sample. Their results are robust—marginal costs have a significant impact on short-run inflation dynamics and forward-looking behaviour is always found to be important.

In the same manner as above, equation (8.13) can be written as

$$\Delta p_{t+1} = \frac{1}{b^f_{p1}} \Delta p_t - \frac{b^b_{p1}}{b^f_{p1}} \Delta p_{t-1} - \frac{b_{p2}}{b^f_{p1}} x_t - \frac{1}{b^f_{p1}} \varepsilon_{pt} + \eta_{t+1} \tag{7.8}$$

and combined with (7.3). The characteristic polynomial of the hybrid system is

$$p(\lambda) = \lambda^3 - \left[\frac{1}{b^f_{p1}} + b_{x2} \right] \lambda^2 + \frac{1}{b^f_{p1}} \left[b^b_{p1} + b_{p2} b_{x1} + b_{x2} \right] \lambda - \frac{b^b_{p1}}{b^f_{p1}} b_{x2}. \tag{7.9}$$

Using the typical results for the expectation and backward-looking parameters, $b^f_{p1} = 0.25$, $b^b_{p1} = 0.75$, together with the assumption of an exogenous x_t

process with autoregressive parameter 0.7, we obtain the roots {3.0, 1.0, 0.7}.[5] Thus, there is no asymptotically stable stationary solution for the rate of inflation in this case.

This seems to be a common result for the hybrid model as several authors choose to impose the restriction

$$b_{p1}^{f} + b_{p1}^{b} = 1, \tag{7.10}$$

which forces a unit root upon the system. To see this, note first that a 1–1 reparameterisation of (7.8) gives

$$\Delta^2 p_{t+1} = \left[\frac{1}{b_{p1}^{f}} - \frac{b_{p1}^{b}}{b_{p1}^{f}} - 1\right]\Delta p_t + \frac{b_{p1}^{b}}{b_{p1}^{f}}\Delta^2 p_t - \frac{b_{p2}}{b_{p1}^{f}}x_t - \frac{1}{b_{p1}^{f}}\varepsilon_{pt} + \eta_{t+1},$$

so that if (7.10) holds, (7.8) reduces to

$$\Delta^2 p_{t+1} = \frac{(1-b_{p1}^{f})}{b_{p1}^{f}}\Delta^2 p_t - \frac{b_{p2}}{b_{p1}^{f}}x_t - \frac{1}{b_{p1}^{f}}\varepsilon_{pt} + \eta_{t+1}. \tag{7.11}$$

Hence, the homogeneity restriction (7.10) turns the hybrid model into a model of the *change* in inflation. Equation (7.11) is an example of a model that is cast in the difference of the original variable, a so-called differenced autoregressive model (dVAR), only modified by the driving variable x_t. Consequently, it represents a generalisation of the random walk model of inflation that was implied by setting $b_{p1}^{f} = 1$ in the original NPCM. The result in (7.11) will prove important in understanding the behaviour of the NPCM in terms of goodness of fit, see later.

If the process x_t is strongly exogenous, the NPCM in (7.11) can be considered on its own. In that case (7.11) has no stationary solution for the rate of inflation. A necessary requirement is that there are equilibrating mechanisms elsewhere in the system, specifically in the process governing x_t (e.g. the wage share). This requirement parallels the case of dynamic homogeneity in the backward-looking Phillips curve (i.e. a vertical long-run Phillips curve). In the present context, the message is that statements about the stationarity of the rate of inflation, and the nature of the solution (backward or forward) requires an analysis of the system.

The empirical results of GG and GGL differ from other studies in two respects. First, b_{p1}^{f} is estimated in the region (0.65, 0.85) whereas b_{p1}^{b} is one third of b_{p1}^{f} or less. Second, GG and GGL succeed in estimating the hybrid model without imposing (7.10). GGL (their table 2) report the estimates $\{0.69, 0.27\}$ and $\{0.88, 0.025\}$ for two different estimation techniques. The corresponding roots are $\{1.09, 0.70, 0.37\}$ and $\{1.11, 0.70, 0.03\}$, illustrating that as long as the sum of the weights is less than one the future dependent solution prevails.

[5] The full set of coefficient values are: $b_{x1} = 0$, $b_{p1}^{f} = 0.25$, $b_{p1}^{b} = 0.75$, $b_{x2} = 0.7$.

7.4 Sensitivity analysis

In the following, we will focus on the results in GGL for the Euro area. Our replication of their estimates is given in (7.12), using the same set of instruments: five lags of inflation, and two lags of the wage share, detrended output, and wage inflation.

$$\Delta p_t = \underset{(0.073)}{0.681}\Delta p_{t+1} + \underset{(0.072)}{0.281}\Delta p_{t-1} + \underset{(0.027)}{0.019}ws_t + \underset{(0.069)}{0.063} \tag{7.12}$$

$$\text{GMM},\ T = 107\ (1971(3)\ \text{to}\ 1998(1))$$
$$\chi^2_{\mathsf{J}}(8) = 8.01[0.43],$$

where $\chi^2_{\mathsf{J}}(\cdot)$ is Hansen's (1982) J-test of overidentifying restrictions. The role of the wage share (as a proxy for real marginal costs) is a definable trait of the NPCM, yet the empirical relevance of ws_t is not apparent in (7.12): it is statistically insignificant. Note also that the sum of the coefficients of the two inflation terms is 0.96. Taken together, the insignificance of ws_t and the near unit-root, imply that (7.12) is almost indistinguishable from a pure time-series model, a dVAR.[6] On the other hand, the formal significance of the forward term, and the insignificance of the J-statistic corroborate the NPCM. The merits of the J-statistic are discussed in Section 7.5: in the rest of this section we conduct a sensitivity analysis with regards to GMM estimation methodology.

The results in (7.12) were obtained by a GMM procedure which computes the weighting matrix once. When instead we iterate over both coefficients and weighting matrix, with fixed bandwidth,[7] we obtain

$$\Delta p_t = \underset{(0.052)}{0.731}\Delta p_{t+1} + \underset{(0.069)}{0.340}\Delta p_{t-1} - \underset{(0.029)}{0.042}ws_t - \underset{(0.070)}{0.102} \tag{7.13}$$

$$\text{GMM},\ T = 107\ (1971(3)\ \text{to}\ 1998(1))$$
$$\chi^2_{\mathsf{J}}(8) = 7.34[0.50].$$

As before, there is clear indication of a unit root (the sum of the two inflation coefficients is now slightly above one). The wage share coefficient is wrongly signed, but it is still insignificantly different from zero, though.

Next, we investigate the robustness with regard to the choice of instruments. We use an alternative output-gap measure ($emugap_t$), which is a simple transformation of the one defined in Fagan *et al.* (2001) as real output relative to potential output, measured by a constant-return-to-scale Cobb–Douglas production function with neutral technical progress. We also omit the two lags

[6] See Bårdsen *et al.* (2002*b*) for a more detailed discussion.

[7] We used the default GMM implementation in Eviews 4.

of wage growth. Apart from yet another sign-change in the ws coefficient, the results respond little to these changes in the set of instruments:

$$\Delta p_t = \underset{(0.06)}{0.60}\Delta p_{t+1} + \underset{(0.06)}{0.35}\Delta p_{t-1} + \underset{(0.03)}{0.03}ws_t + \underset{(0.06)}{0.08} \tag{7.14}$$

$$\text{GMM}, \ T = 107 \ (1972(4) \text{ to } 1997(4))$$
$$\chi^2_{\mathsf{J}}(6) = 6.74[0.35].$$

Finally, we investigate the robustness with respect to estimation method. Since the NPCM is a linear model, the only real advantage of choosing GMM as opposed to 2SLS as estimation method is the potential necessity to correct for autocorrelated residuals. Autocorrelation is in line with the rational expectations hypothesis, implied by replacing $E_t\Delta p_{t+1}$ with Δp_{t+1} in estimation—see Blake (1991) and Appendix A.2—but it may also be a symptom of mis-specification, as discussed in Nymoen (2002). As shown below, the estimates are robust with respect to estimation method, even though the standard errors are doubled, since the model suffers from severe autocorrelation:

$$\Delta p_t = \underset{(0.14)}{0.66}\Delta p_{t+1} + \underset{(0.12)}{0.28}\Delta p_{t-1} + \underset{(0.09)}{0.07}ws_t + \underset{(0.12)}{0.10} \tag{7.15}$$

$$\text{2SLS}, \ T = 104 \ (1972(2) \text{ to } 1998(1))$$

$\hat{\sigma}_{IV} = 0.28$ RSS $= 7.66$
$\mathsf{F}_{\mathsf{AR}(1-1)}(1,99) = 166.93[0.00]$ $\mathsf{F}_{\mathsf{AR}(2-2)}(1,99) = 4.73[0.03]$
$\mathsf{F}_{\mathsf{ARCH}(1-4)}(4,92) = 2.47[0.05]$ $\chi^2_{\mathsf{normality}}(2) = 1.59[0.45]$
$\mathsf{F}_{\mathsf{HET}x_ix_j}(9,90) = 2.34[0.02]$ $\chi^2_{\mathsf{ival}}(6) = 11.88[0.06]$
$\mathsf{F}_{\mathsf{irel}}(9,94) = 70.76[0.00].$

The p-value of the Sargan specification test, χ^2_{ival}, is 0.06, and indicates that (7.15) could be mis-specified, since some of the instruments could be potential regressors. The $\mathsf{F}_{\mathsf{irel}}$ is the F-statistic from the first stage regression of Δp_{t+1} against the instrument set and indicates no 'weak instruments' problem, although it is only strictly valid in the case of one endogenous regressor—see Stock *et al.* (2002).[8]

We conclude from the range of estimates that the significance of the wage share is fragile and that its formal statistical significance depends on the exact implementation of the estimation method used. The coefficient of the forward variable on the other hand is pervasive and will be a focal point of the following analysis. Residual autocorrelation is another robust feature, as also noted by GGL. But more work is needed before we can judge whether autocorrelation really corroborates the theory, which is GGL's view, or whether it is a sign of econometric mis-specification.

[8] The rule of thumb is a value bigger than 10 in the case of one endogenous regressor.

7.5 Testing the specification

The main tools of evaluation of models like the NPCM have been the GMM test of validity of overidentifying restrictions (i.e. the χ^2_J-test earlier) and measures and graphs of goodness-of-fit.[9] Neither of these tests is easy to interpret. First, the χ^2_J may have low power. Second, the estimation results reported by GG and GGL yield values of $b^f_{p1} + b^b_{p1}$ close to 1 while the coefficient of the wage share is numerically small. This means that the apparently good fit is in fact no better (or worse) than a model in the double differences (e.g. a random walk); see Bårdsen *et al.* (2002*b*). There is thus a need for other evaluation methods, and in the rest of this chapter we test the NPCM specification against alternative models of the inflation process.

7.5.1 An encompassing representation

The main alternatives to the NPCM as models of inflation are the Standard Phillips Curve Model (PCM) and the Incomplete Competition Model (ICM). They will therefore be important in suggesting ways of evaluating the NPCM from an encompassing perspective. To illustrate the main differences between alternative specifications, consider the following stylised framework—see also Bårdsen *et al.* (2002*a*). Let w be wages and p consumer prices; with a as productivity, the wage share ws is given as real unit labour costs: $ws = ulc - p = w - a - p$; u is the unemployment rate, and gap the output gap, all measured in logs. We abstract from other forcing variables, like open economy aspects. A model of the wage–price process general enough for the present purpose then takes the form

$$\Delta w = \alpha \Delta p^e - \beta ws - \gamma u,$$
$$\Delta p = \delta \Delta p^e + \zeta \Delta w + \eta ws + \vartheta gap,$$

where Δp^e is expected inflation, and the dynamics are to be specified separately for each model. Although the structure is very simple, the different models drop out as non-nested special cases:

1. The NPCM is given as

$$\Delta p_t = \delta^f_1 \Delta p^e_{t+1} + \delta^b_1 \Delta p_{t-1} + \eta_1 ws_t,$$

   where the expectations term Δp^e_{t+1} is assumed to obey rational expectations.

[9] For example, in the *Abstract* of GGL the authors state that 'the NPC fits Euro data very well, possibly better than United States data'. Also Galí (2003), responding to critical assessments of the NPCM, states that 'it appears to fit the data much better than had been concluded by the earlier literature'.

2. The PCM is—Aukrust (1977), Calmfors (1977), Nymoen (1990), Blanchard and Katz (1997):

$$\Delta w_t = \alpha_2 \Delta p_t - \gamma_2 u_t$$
$$\Delta p_t = \zeta_2 \Delta w_t + \vartheta_2 gap_t.$$

3. The ICM on equilibrium correction form—Sargan (1964), Layard *et al.* (1991), Bårdsen *et al.* (1998), and Kolsrud and Nymoen (1998):

$$\Delta w_t = \alpha_3 \Delta p_t - \beta_3 (ws - \gamma_2 u)_{t-1}$$
$$\Delta p_t = \zeta_3 \Delta w_t - \delta_1^b [p - \eta_3 (ws + p)]_{t-1} + \vartheta_3 gap_{t-1}.$$

Of course, there exist a host of other, more elaborate, models—a notable omission being non-linear PCMs. However, the purpose here is to highlight that discrimination between the models is possible through testable restrictions. The difference between the two Phillips curve models is that the NPCM has forward-looking expectations and has real unit labour costs, rather than the output gap of the PCM. In the present framework, the ICM differs mainly from the NPCM in the treatment of expectations and from the PCM in the latter's exclusion of equilibrium correction mechanisms that are derived from conflict models of inflation; see Rowthorn (1977), Sargan (1980), Kolsrud and Nymoen (1998), Bårdsen and Nymoen (2003) and Chapter 6. To see this, note that the NPCM can, trivially, be reparameterised as a forward-looking equilibrium-correction model (EqCM) with long-run coefficient restricted to unity:

$$\Delta p_t = \delta_1^f \Delta p_{t+1}^e + \eta_1 \Delta ws_t + \delta_1^b \Delta p_{t-1} - \eta_1 [p - 1(ws + p)]_{t-1}.$$

The models listed in 1–3 are identified, in principle, but it is an open question whether data and methodology are able to discriminate between them on a given data set. We therefore test the various identifying restrictions. This will involve testing against

- richer dynamics
- system representations
- encompassing restrictions.

We next demonstrate these three approaches in practice.

7.5.2 Testing against richer dynamics

In the case of the NPCM, the specification of the econometric model used for testing a substantive hypothesis—forward and lagged endogenous variable—incorporates the alternative hypothesis associated with a mis-specification test (i.e. of residual autocorrelation). Seeing residual correlation as corroborating the theory that agents are acting in accordance with NPCM is invoking a very strong *ceteris paribus* clause. Realistically, the underlying cause of the residual correlation may of course be quite different, for example, omitted variables, wrong functional form or, in this case, a certain form of over-differencing. In fact, likely directions for respecification are suggested by pre-existing results from several decades of empirical modelling of inflation dynamics. For example, variables representing capacity utilisation (output-gap and/or unemployment) have a natural role in inflation models: we use the alternative output-gap measure ($emugap_t$). Additional lags in the rate of inflation are also obvious candidates. As a direct test of this respecification, we move the lagged output-gap ($emugap_{t-1}$) and the fourth lag of inflation (Δp_{t-4}) from the list of instruments used for estimation of (7.14), and include them as explanatory variables in the equation. The results (using 2SLS) are:

$$\begin{aligned}\Delta p_t = &\underset{(0.28)}{0.07}\Delta p_{t+1} + \underset{(0.09)}{0.14} ws_t + \underset{(0.14)}{0.44}\Delta p_{t-1} \\ &+ \underset{(0.09)}{0.18}\,\Delta p_{t-4} + \underset{(0.05)}{0.12}\, emugap_{t-1} + \underset{(0.30)}{0.53}\end{aligned} \tag{7.16}$$

$$\text{2SLS},\ T = 104\ (1972(2)\text{ to }1998(1))$$

$$\begin{array}{ll}\hat{\sigma}_{IV} = 0.28 & \text{RSS} = 7.52 \\ \mathsf{F}_{\mathsf{AR}(1-1)}(1,97) = 2.33[0.13] & \mathsf{F}_{\mathsf{AR}(2-2)}(1,97) = 2.80[0.10] \\ \mathsf{F}_{\mathsf{ARCH}(1-4)}(4,90) = 0.80[0.53] & \chi^2_{\mathsf{normality}}(2) = 1.75[0.42] \\ \mathsf{F}_{\mathsf{HET}x_ix_j}(20,77) = 1.26[0.23] & \chi^2_{\mathsf{ival}}(4) = 4.52[0.34].\end{array}$$

When compared to (7.14) and (7.15), four results stand out:

1. The estimated coefficient of the forward term Δp_{t+1} is reduced by a factor of 10, and becomes insignificant.
2. The diagnostic tests indicate no residual autocorrelation or heteroskedasticity.
3. The p-value of the Sargan specification test, χ^2_{ival}, is 0.34, and is evidence that (7.16) effectively represents the predictive power that the set of instruments has about Δp_t.[10]
4. If the residual autocorrelations of the NPCMs above are induced by the forward solution and 'errors in variables', there should be a similar autocorrelation process in the residuals of (7.16). Since there is no detectable residual autocorrelation, that interpretation is refuted, supporting instead that the hybrid NPCM is mis-specified.

Finally, after deleting Δp_{t+1} from the equation, the model's interpretation is clear, namely as a conventional dynamic price-setting equation. Indeed, using the framework of Section 7.5.1, the model is seen to correspond to the ICM price equation, with $\delta_1^f = 0$ (and extended with Δp_{t-4} and $emugap_{t-1}$ as explanatory

[10] The full set of instruments is: ws_{t-1}, ws_{t-2}, Δp_{t-2}, Δp_{t-3}, Δp_{t-5}, and $emugap_{t-2}$.

variables). We are therefore effectively back to a conventional dynamic markup equation.

In sum, we find that significance testing of the forward term does not support the NPCM for the Euro data. This conclusion is based on the premise that the equation with the forward coefficient is tested *within* a statistically adequate model, which entails thorough mis-specification testing of the theoretically postulated NPCM, and possible respecification before the test of the forward coefficient is performed. Our results are in accord with Rudd and Whelan (2004), who show that the tests of forward-looking behaviour which Galí and Gertler (1999) and Galí *et al.* (2001) rely on, have very low power against alternative, but non-nested, backward-looking specifications, and demonstrate that results previously interpreted as evidence for the New Keynesian model are also consistent with a backward-looking Phillips curve. Rudd and Whelan develop alternative, more powerful tests, which exhibit a very limited role for forward-looking expectations. A complementary interpretation follows from a point made by Mavroeidis (2002), namely that the hybrid NPCM suffers from underidentification, and that in empirical applications identification is achieved by confining important explanatory variables to the set of instruments, with mis-specification as a result.

7.5.3 Evaluation of the system

The nature of the solution for the rate of inflation is a system property, as noted in Section 7.3. Hence, unless one is willing to accept at face value that an operational definition of the forcing variable is strongly exogenous, the 'structural' NPCM should be evaluated within a system that also includes the forcing variable as a modelled variable.

For that purpose, Table 7.1 shows an estimated system for Euro-area inflation, with a separate equation (the second in the table) for treating the wage share (the forcing variable) as an endogenous variable. Note that the hybrid NPCM equation (first in the table) is similar to (7.14), and thus captures the gist of the results in GGL. This is hardly surprising, since only the estimation method (full information maximum likelihood—FIML in Table 7.1) separates the two NPCMs.

An important feature of the estimated equation for the wage share ws_t is the two lags of the rate of inflation, which both are highly significant. The likelihood-ratio test of joint significance gives $\chi^2(2) = 24.31[0.00]$, meaning that there is clear formal evidence against the strong exogeneity of the wage share. One further implication of this result is that a closed form solution for the rate of inflation cannot be derived from the structural NPCM alone.

The roots of the system in Table 7.1 are all less than one (not shown in the table) in modulus and therefore corroborate a forward solution. However, according to the results in the table, the implied driving variable is $emugap_t$, rather than ws_t which is endogenous, and the weights of the present value

Table 7.1
FIML results for the NPCM system for the Euro area 1972(2)–1998(1)

$$\Delta p_t = \underset{(0.154)}{0.7696}\Delta p_{t+1} + \underset{(0.131)}{0.2048}\Delta p_{t-1} + \underset{(0.0930)}{0.0323} ws_t + \underset{(0.1284)}{0.0444}$$

$$ws_t = \underset{(0.0296)}{0.8584} ws_{t-1} + \underset{(0.0220)}{0.0443}\Delta p_{t-2} + \underset{(0.0223)}{0.0918}\Delta p_{t-5} + \underset{(0.0067)}{0.0272}\, emugap_{t-2} - \underset{(0.0447)}{0.2137}$$

$$\Delta p_{t+1} = \underset{(0.0988)}{0.5100} ws_{t-1} + \underset{(0.0907)}{0.4153}\Delta p_{t-1} + \underset{(0.0305)}{0.1814}\, emugap_{t-1} + \underset{(0.1555)}{0.9843}$$

Note: The sample is 1972(2) to 1998(1), $T = 104$.

$$\hat{\sigma}_{\Delta p_t} = 0.290186$$
$$\hat{\sigma}_{ws} = 0.074904$$
$$\hat{\sigma}_{\Delta p^e_{t+1}} = 0.325495$$
$$\mathsf{F}^v_{\mathsf{AR}(1-5)}(45, 247) = 37.100[0.0000]^{**}$$
$$\mathsf{F}^v_{\mathsf{HET}x^2}(108, 442) = 0.94319[0.6375]$$
$$\mathsf{F}^v_{\mathsf{HET}x_i x_j}(324, 247) = 1.1347[0.1473]$$
$$\chi^{2,v}_{\mathsf{normality}}(6) = 9.4249[0.1511]$$

calculation of $emugap_t$ have to be obtained from the full system. The statistics at the bottom of the table show that the system of equations has clear deficiencies as a statistical model, cf. the massive residual autocorrelation detected by $\mathsf{F}^v_{\mathsf{AR}(1-5)}$. Further investigation indicates that this problem is in part due to the wage share residuals and is not easily remedied on the present information set. However, from Section 7.5.2 we already know that another source of vector autocorrelation is the NPCM itself, and moreover that this mis-specification by and large disappears if we instead adopt equation (7.16) as our inflation equation.

It lies close at hand therefore to suggest another system where we utilise the second equation in Table 7.1, and the conventional price equation that is obtained by omitting the insignificant forward term from equation (7.16). Table 7.2 shows the results of this potentially useful model. No mis-specification is detected, and the coefficients appear to be well determined. In terms of economic interpretation the models resemble an albeit 'watered down' version

Table 7.2
FIML results for a conventional Phillips curve for the Euro area 1972(2)–1998(1)

$$\Delta p_t = \underset{(0.1202)}{0.2866} ws_t + \underset{(0.0868)}{0.4476} \Delta p_{t-1} + \underset{(0.091)}{0.1958} \Delta p_{t-4} + \underset{(0.0259)}{0.1383}\, emugap_{t-1} + \underset{(0.1823)}{0.6158}$$

$$ws_t = \underset{(0.0298)}{0.8629} ws_{t-1} + \underset{(0.0222)}{0.0485} \Delta p_{t-2} + \underset{(0.0225)}{0.0838} \Delta p_{t-5} + \underset{(0.0068)}{0.0267}\, emugap_{t-2} - \underset{(0.0450)}{0.2077}$$

Note: The sample is 1972(2) to 1998(1), $T = 104$.

$$\hat{\sigma}_{\Delta p_t} = 0.284687$$
$$\hat{\sigma}_{ws} = 0.075274$$
$$\mathsf{F}^v_{\mathsf{AR}(1-5)}(20, 176) = 1.4669[0.0983]$$
$$\mathsf{F}^v_{\mathsf{HET}x^2}(54, 233) = 0.88563[0.6970]$$
$$\mathsf{F}^v_{\mathsf{HET}x_ix_j}(162, 126) = 1.1123[0.2664]$$
$$\chi^{2,v}_{\mathsf{normality}}(4) = 2.9188[0.5715]$$
$$\chi^2_{\mathsf{overidentification}}\ (10) = 10.709[0.3807]$$

of the modern conflict model of inflation and one interesting route for further work lies in that direction. That would entail an extension of the information set to include open economy aspects and indicators of institutional developments and of historical events. The inclusion of such features in the information set will also help in stabilising the system.[11]

7.5.4 Testing the encompassing implications

So far the NPCM has mainly been used to describe the inflationary process in studies concerning the United States economy or for aggregated Euro data. Heuristically, we can augment the basic model with import price growth and other open economy features, and test the significance of the forward inflation rate within such an extended NPCM. Recently, Batini *et al.* (2000) have derived an open economy NPCM from first principles, and estimated the model on United Kingdom economy data. Once we consider the NPCM for individual European economies, there are new possibilities for testing—since pre-existing results should, in principle, be explained by the new model (the NPCM). Specifically, and as discussed in earlier chapters, in the United Kingdom there exist models of inflation that build on a different framework than the

[11] The largest root in Table 7.2 is 0.98.

NPCM, namely wage bargaining and cointegration; see, for example, Nickell and Andrews (1983), Hoel and Nymoen (1988), Nymoen (1989*a*), and Blanchard and Katz (1999). Since the underlying theoretical assumptions are quite different, the existing empirical models define an information set that is wider than the set of instruments that are typically employed in the estimation of NPCMs. In particular, the existing studies claim to have found cointegrating relationships between levels of wages, prices, and productivity. These relationships constitute evidence that can be used to test the implications of the NPCM.

Specifically, the following procedure is followed[12]:

1. Assume that there exists a set of variables $\mathbf{z} = [\mathbf{z}_1 \;\; \mathbf{z}_2]$, where the sub-set $\mathbf{z}_1$ is sufficient for identification of the maintained NPCM model. The variables in $\mathbf{z}_2$ are defined by the empirical findings of existing studies.
2. Using $\mathbf{z}_1$ as instruments, estimate the augmented model
$$\Delta p_t = b_{p1}^f \mathsf{E}_t \Delta p_{t+1} + b_{p1}^b \Delta p_{t-1} + b_{p2} x_t + \cdots + \mathbf{z}_{2,t} \mathbf{b}_{p4}$$
under the assumption of rational expectations about forward prices.
3. Under the hypothesis that the NPCM is the correct model, $\mathbf{b}_{p4} = \mathbf{0}$ is implied. Thus, non-rejection of the null hypothesis of $\mathbf{b}_{p4} = \mathbf{0}$, corroborates the feed-forward Phillips curve. In the case of the other outcome: non-rejection of $b_{p1}^f = 0$, while $\mathbf{b}_{p4} = \mathbf{0}$ is rejected statistically, the encompassing implication of the NPCM is refuted.

The procedure is clearly related to significance testing of the forward term, but there are also notable differences. As mentioned above, the motivation of the test is that of testing the implication of the rational expectations hypothesis; see Hendry and Neale (1988), Favero and Hendry (1992), and Ericsson and Irons (1995). Thus, we utilise that under the assumption that the NPCM is the correct model, consistent estimation of b_{p1}^f can be based on $\mathbf{z}_1$, and supplementing the set of instruments by $\mathbf{z}_2$ should not significantly change the estimated b_{p1}^f.

In terms of practical implementation, we take advantage of the existing results on wage and price modelling using cointegration analysis which readily imply z_2-variables in the form of linear combinations of levels variables. In other words they represent 'unused' identifying instruments that go beyond information sets used in the Phillips curve estimation. Importantly, if agents are rational, the extension of the information set should not take away the significance of Δp_{t+1} in the NPCM, and $\mathbf{b}_{p4} = \mathbf{0}$.

As mentioned earlier, Batini *et al.* (2000) derive an open economy NPCM consistent with optimising behaviour, thus extending the intellectual rationale of the original NPCM. They allow for employment adjustment costs, hence both future and current employment growth is included (Δn_{t+1} and Δn_t), and

[12] David F. Hendry suggested this test procedure to us. Bjørn E. Naug pointed out to us that a similar procedure is suggested in Hendry and Neale (1988).

propose to let the equilibrium markup on prices depend on the degree of foreign competition, *com*. In their estimated equations, they also include a term for the relative price of imports, denoted *rpi* and oil prices *oil*. The wage share variable used is the adjusted share preferred by Batini *et al.* (2000). Equation (7.17) is our attempt to replicate their results, with GMM estimation using their data.[13]

$$\begin{aligned}\Delta p_t = &- \underset{(0.20)}{0.56} + \underset{(0.09)}{0.33}\Delta p_{t+1} + \underset{(0.04)}{0.32}\Delta p_{t-1} + \underset{(0.06)}{0.07}\,gap_t \\ &+ \underset{(0.01)}{0.02}\,com_t + \underset{(0.05)}{0.13}ws_t - \underset{(0.01)}{0.004}\ rpi_t - \underset{(0.003)}{0.02}\ \Delta oil_t \\ &- \underset{(0.42)}{0.79}\Delta n_{t+1} + \underset{(0.39)}{1.03}\Delta n_t \end{aligned} \tag{7.17}$$

$$\text{GMM},\ T = 107\ (1972(3)\ \text{to}\ 1999(1)),\quad \hat{\sigma} = 0.0099$$
$$\chi^2_{\mathsf{J}}(31) = 24.92[0.77],\quad \mathsf{F}_{\mathsf{irel}}(40, 66) = 8.29[0.00].$$

The terms in the second line represent small open economy features that we noted above. The estimated coefficients are in accordance with the results that Batini *et al.* (2000) report. However, the $\mathsf{F}_{\mathsf{irel}}$, which still is the F-statistic from the first stage ordinary least squares (OLS) regression of Δp_{t+1} against the instrument set, indicates that their model might have a potential problem of weak instruments.

In Section 5.6 we saw how Bårdsen *et al.* (1998) estimate a simultaneous cointegrating wage–price model for the United Kingdom (see also Bårdsen and Fisher 1999). Their two equilibrium-correction terms are deviations from a long-run wage-curve and an open economy price markup (see Panel 5 of Table 5.3):

$$ecmw_t = (w - p - a + \tau 1 + 0.065u)_t, \tag{7.18}$$
$$ecmp_t = (p - 0.6\tau 3 - 0.89(w + \tau 1 - a) - 0.11pi)_t, \tag{7.19}$$

where a denotes average labour productivity, $\tau 1$ is the payroll tax rate, u is the unemployment rate and pi is the price index of imports. The first instrument, $ecmw_t$, is an extended wage share variable which we expect to be a better instrument than ws_t, since it includes the unemployment rate as implied by, for example, bargaining models of wage-setting (see the encompassing representation of Section 7.5.1). The second instrument, $ecmp_t$, is an open economy version of the long-run price markup of the stylised ICM in Section 7.5.1.[14]

[13] Although we use the same set of instruments as Batini *et al.* (2000), we are unable to replicate their table 7b, column (b). Inflation is the first difference of log of the gross value added deflator. The *gap* variable is formed using the Hodrick–Prescott (HP) trend; see Batini *et al.* (2000) (footnote to tables 7a and 7b) for more details.

[14] Inflation Δp_t in equation (7.17) is for the gross value added price deflator, while the price variable in the study by Bårdsen *et al.* (1998) is the retail price index pc_t. However, if the long-run properties giving rise to the *ecms* are correct, the choice of price index should not matter. We therefore construct the two *ecm*s in terms of the GDP deflator, p_t, used by Batini *et al.* (2000).

Equation (7.20) shows the results, for the available sample 1976(2)–1996(1), of adding $ecmw_{t-1}$ and $ecmp_{t-1}$ to the NPCM model (7.17):

$$\begin{aligned}\Delta p_t = &- \underset{(0.44)}{1.51} + \underset{(0.13)}{0.03}\Delta p_{t+1} + \underset{(0.08)}{0.24}\Delta p_{t-1} - \underset{(0.11)}{0.02}\,gap_t + \underset{(0.019)}{0.008}\,com_t \\ &+ \underset{(0.07)}{0.13}ws_t - \underset{(0.03)}{0.01}\,rpi_t - \underset{(0.004)}{0.003}\Delta oil_t + \underset{(0.27)}{0.11}\Delta n_{t+1} \\ &+ \underset{(0.19)}{0.87}\Delta n_t - \underset{(0.10)}{0.35}ecmw_{t-1} - \underset{(0.12)}{0.61}ecmp_{t-1} \end{aligned} \tag{7.20}$$

$$\text{GMM},\ T = 80\ (1976(2)\ \text{to}\ 1996(1)),\quad \hat{\sigma} = 0.0083$$
$$\chi^2_{\mathsf{J}}(31) = 14.39[0.99],\quad \mathsf{F}_{\mathsf{irel}}(42, 37) = 4.28[0.000].$$

The forward term Δp_{t+1} is no longer significant, whereas the ecm-terms, which ought to be of no importance if the NPCM is the correct model, are both strongly significant.[15]

In the same vein, note that our test of GGL's Phillips curve for the Euro area in Section 7.5.2 can be interpreted as a test of the implications of rational expectations. There $\mathbf{z}_2$ was simply made up of Δp_{t-4} and $emugap_{t-1}$ which modelling experience tells us are predictors of future inflation. Thus, from rational expectations their coefficients should be insignificant when Δp_{t+1} is included in the model (and there are good, overidentifying instruments). Above, we observed the converse, namely Δp_{t-4} and $emugap_{t-1}$ are statistically and numerically significant, while the estimated coefficient of Δp_{t+1} was close to zero.

7.5.5 The NPCM in Norway

Consider the NPCM (with forward term only) estimated on quarterly Norwegian data[16]:

$$\Delta p_t = \underset{(0.11)}{1.06}\ \Delta p_{t+1} + \underset{(0.02)}{0.01}\ ws_t + \underset{(0.02)}{0.04}\ \Delta pi_t + \text{dummies} \tag{7.21}$$

$$\chi^2_{\mathsf{J}}(10) = 11.93[0.29].$$

The closed economy specification has been augmented heuristically with import price growth (Δpi_t) and dummies for seasonal effects as well as special events in the economy described in Bårdsen *et al.* (2002*b*). Estimation is by GMM for the period 1972(4)–2001(1). The instruments used (i.e. the variables in $\mathbf{z}_1$) are lagged wage growth (Δw_{t-1}, Δw_{t-2}), lagged inflation (Δp_{t-1}, Δp_{t-2}), lags of level and change in unemployment (u_{t-1}, Δu_{t-1}, Δu_{t-2}), and changes in

[15] The conclusion is unaltered when the two instruments are defined in terms of pc_t, as in the original specification of Bårdsen *et al.* (1998).

[16] Inflation is measured by the official consumer price index (CPI).

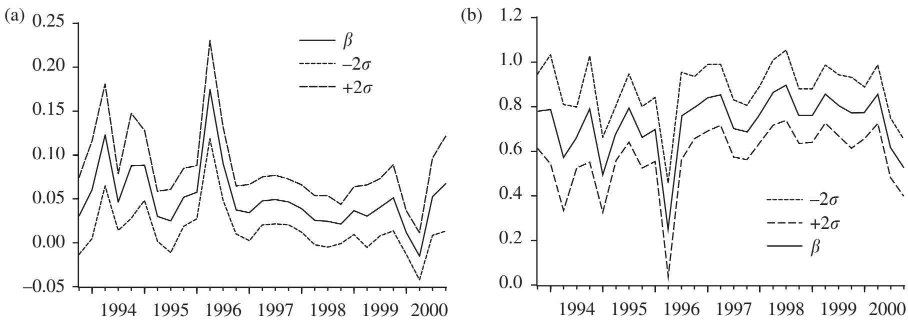

Figure 7.2. Rolling coefficients ±2 standard errors of the NPCM, estimated on Norwegian data ending in 1993(4)–2000(4). Graph (a) shows the coefficient of ws_t and graph (b) shows the coefficient of Δp_{t+1}.

energy prices (Δpe_t, Δpe_{t-1}), the short term interest rate (ΔRL_t, ΔRL_{t-1}), and the length of the working day (Δh_t).

The coefficient estimates are similar to GG. Strictly speaking, the coefficient of $\mathsf{E}[\Delta p_{t+1} \mid \mathcal{I}_t]$ suggests that a backward solution is appropriate. But more importantly the estimated NPCM once more appears to be a modified random walk model. We also checked the stability of the key parameters of the model by rolling regressions with a fixed window of 85 observations. Figure 7.2 shows that the sample dependency is quite pronounced in the case of Norway.

Next, we define an equilibrium correction term from the results in Bårdsen *et al.* (2003) and use that variable as the additional instrument, $z_{2,t}$:

$$ecmp_t = p_t - 0.6(w_t - a_t + \tau 1_t) - 0.4pi_t + 0.5\tau 3_t.$$

The results, using GMM, are

$$\Delta p_t = \underset{(0.125)}{-0.02}\,\Delta p_{t+1} + \underset{(0.025)}{0.04}\; ws_t - \underset{(0.017)}{0.06}\;\Delta pi_t - \underset{(0.020)}{0.10}\; ecmp_{t-1} + \text{dummies}$$

$$\chi^2_{\mathsf{J}}(10) = 12.78[0.24],$$

showing that the implication of the NPCM is refuted by the finding of (1) a highly significant (price) equilibrium correction term defined by an existing study, and (2) the change in the estimated coefficient of Δp_{t+1}, from 1.06 and statistical significance, to -0.02 and no statistical significance.

7.6 Conclusions

Earlier researchers of the NPCM have concluded that the NPCM represents valuable insight into the driving forces of inflation dynamics. Our evaluation gives completely different results. In particular we show that by including variables from the list of instruments as explanatory variables, a statistically adequate model for the Euro area is obtained. In this respecified model, the forward term vanishes, and the Euro area 'inflation equation' can be reinterpreted as a conventional price markup equation. Encompassing implies that a model should be able to explain the results of alternative specifications. In many countries, empirical inflation dynamics is a well researched area, so studies exist that any new model should be evaluated against. Applying the encompassing principle to the NPCM models of United Kingdom inflation as well as Norwegian inflation, leaves no room for the NPCM. The conclusion is that economists should not accept the NPCM too readily.

On the constructive side, our analysis shows that the NPCM can be seen as an equilibrium-correction model augmented by a forward term. This means that although our conclusion refutes the NPCM hypothesis as presently implemented, this does not preclude that forward expectations terms could be found to play a role in explaining inflation dynamics within statistically well-specified models, using the procedures for testing forward terms.