The role of wage formation in empirical macroeconometric models

Ragnar Nymoen

Department of Economics University of Oslo

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Contents

1. Introduction
2. Lineages of wage modelling in macroeconomics
3. A model typology
4. PCM and WP-ECM, specification and properties (examples)
5. NKC

Lineages of wage modelling in macroeconomics

In the beginning, economists were approaching wage formation with great caution:
Samuelson's textbook (3ed 1955, p 547):

> [*wage formation*]*...depends on psychology, politics, and thousands of other intangible factors. As far as the economist is concerned, the final outcome is indeterminate—almost as indeterminate as the haggling between two millionaires over the price paid for a rare oil painting.*

Frisch:

> *A full analysis of how the wage level enters into this complex system of causes, with a numerical representation of the strength of the relationships, can unfortunately not be presented. This is one of the most unfortunate holes in the economic science.* (*Arbeiderbladet 30 August 1945*).

Exogeneity Theory (L-shaped curve)

- In macro what this amounted to was a certain *exogeneity theory* of the wage level, W.
- It was not that W was economy exogenous per se.
- It was that unemployment could vary a lot, without any notable effects on wages and prices in macro (Resounding from Jackson Hole, August 2020)
- However, over the next decades it became common to include estimated equation for wages in the models
- Steve Nickell (1988): the key part of the supply-side are represented by those equations that describe the behaviour of firms, in particular price setting, and those that reflect the determination of wages.

A model of the supply side: w wage level and p the price level; a average labour productivity, the wage-share is defined as $ws = w - a - p$; u is the unemployment rate; all measured in logs

$$\Delta w = \pi_w \Delta p^e + \tau_w \Delta a - \beta_w ws - \sigma_w u$$
$$\Delta p = \pi_p \Delta p^e + \tau_p (\Delta w - \Delta a) + \beta_p ws$$

where Δp^e is "expected inflation" and the dynamics is to be specified for each model. Constant terms and random disturbances are omitted for simplicity.
Although the structure is very simple, the different models drop out as special cases:

1. The Phillips Curve Model (PCM):

$$\Delta w_t = \pi_{w1}\Delta p_t - \sigma_{w1}u_t, \tag{1}$$

$$\Delta p_t = \tau_{p1}(\Delta w_t - \Delta a_t). \tag{2}$$

The first equation the PCM is the wage Phillips curve, hence $0 < \pi_{w1} \leq 1$, $\sigma_{w1} > 0$ and (implicitly) $\beta_{w1} = \tau_w = 0$. If $\pi_{w1} = 1$ the wage PCM is vertical, and the natural rate is determined from that relationship alone (zero here since an intercept is omitted).

2. The wage-price equilibrium correction model (WP-ECM)

$$\Delta w_t = \pi_{w2}\Delta p_t + \tau_{w2}\Delta a_t - \beta_{w2} ws_{t-1} - \sigma_{w2} u_t \quad (3)$$

$$\Delta p_t = \tau_{p2}(\Delta w_t - \Delta a_t) + \beta_{p2} ws_{t-1} \quad (4)$$

In equation (4), the equilibrium, correction variable is simply the lagged wage-share, which implies that static or (long-run) homogeneity is imposed.

3. The New Keynesian Phillips Curve model (NKPCM) is given as

$$\Delta w_t = \Delta p_t + \Delta a_t - \beta_{w3} ws_{t-1} \quad (5)$$

$$\Delta p_t = \pi^f_{p3} \Delta p^e_{t+1} + \pi^b_{p3} \Delta p_{t-1} + \beta_{p3} ws_t, \quad (6)$$

where the expectations term Δp^e_{t+1} in (6) is to be modelled as a conditional expectation (i.e., the rational expectations hypothesis).
To reflect the historical development, this is the "price-NKPC". The "wage-NKPC" came later (see below).

- Section 4 of the paper analyses WP-ECM and PCM by the use of SEMs and VAR framework.
- Section 5 contains one way to bridge the gap between WP-ECM/PCM and the NKPC framework
- The need for a bridge stems from the lead-term, which requires another type of solution than the causal solution.

- Analyse "3-equation systems" for wages, prices and unemployment algebraically and by simulation
- Stability is not trivial (even before structural breaks are introduces)
- If stable, the solutions are in general different for the two model types.
- Therefore, different steady states for unemployment rate.
- With ECM in wage formation:

$$u^{\text{WECM}} = \frac{\theta_w c_u - g_a + (\psi_{wq} + \psi_{wp} - 1) g_{pi}}{\theta_w (1 - \rho) + \varpi \varrho}$$

without any ECM in wage or price formation:

$$u^{\text{PCM}} = \frac{c_w - g_a}{\varphi} + \frac{(\psi_{wq} + \psi_{wp} - 1)}{\varphi} g_{pi}$$

$$u^{\text{WECM}} \neq u^{\text{PCM}}$$

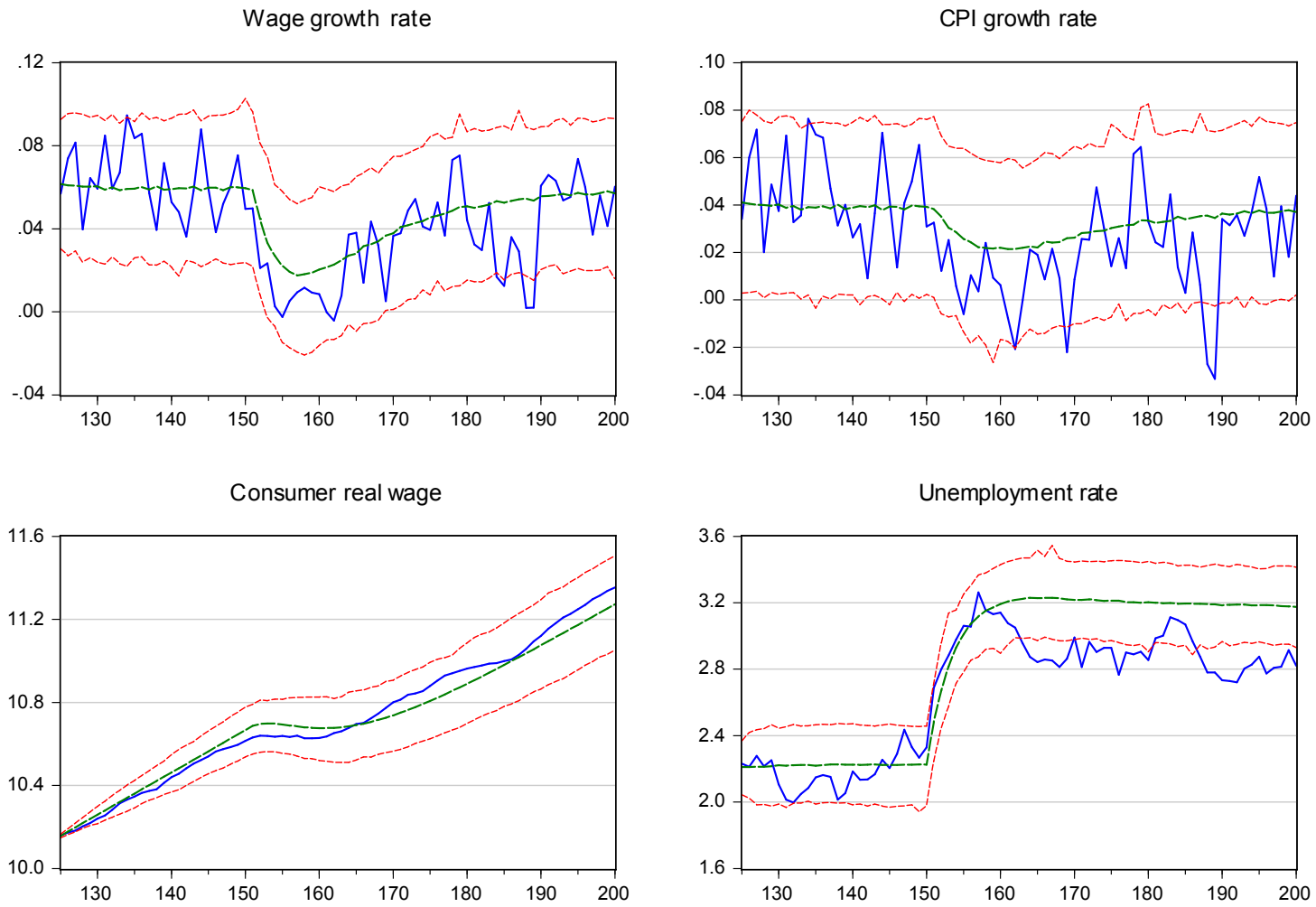


Figure 1: Typical WP-ECM solution paths for endogenous variables shown in graphs with dashed lines, together with 'actuals' (the computer generated time series)

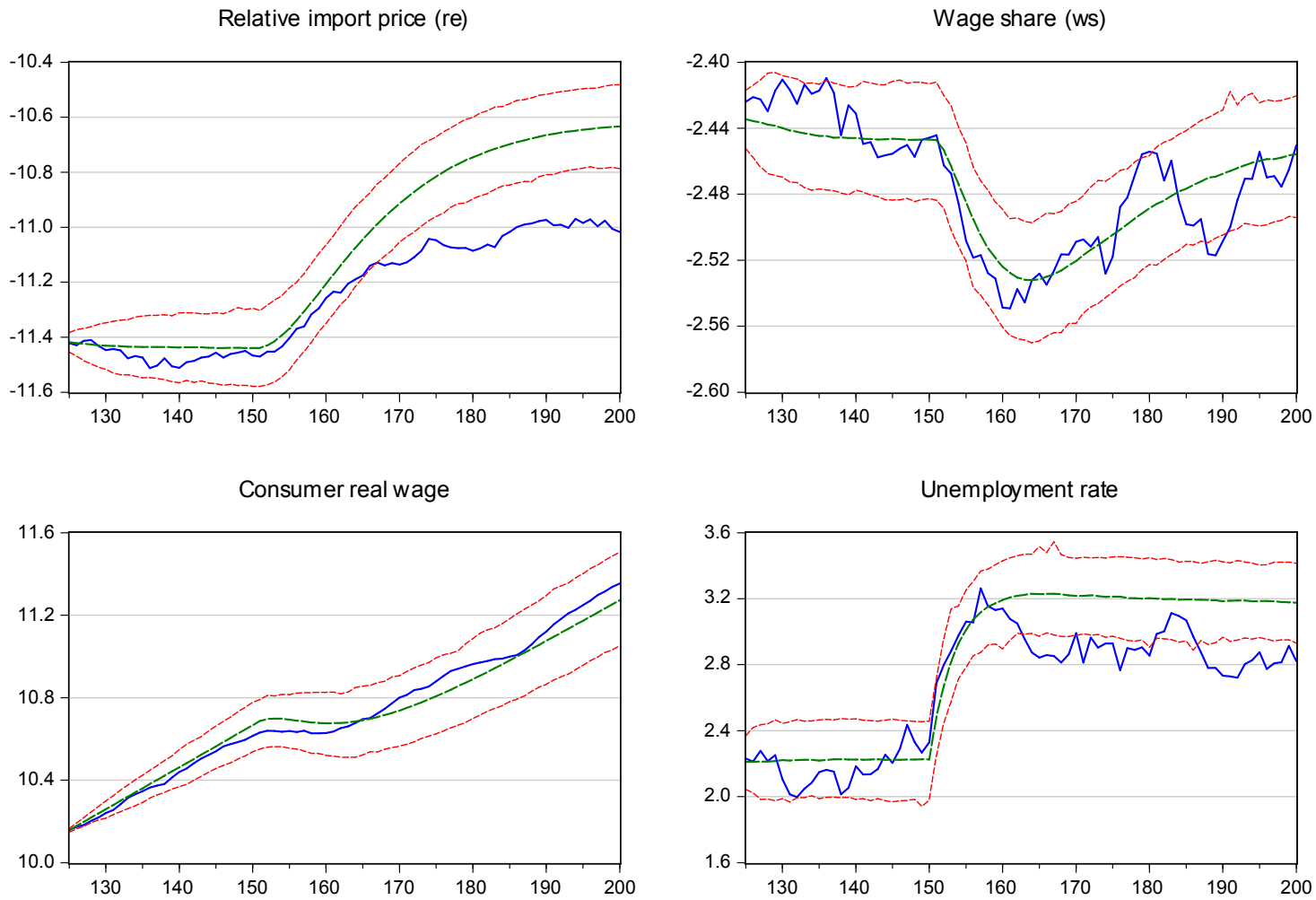


Figure 2: Typical WP-ECM solution paths for endogenous variables shown in graphs with dashed lines, together with 'actuals' (the computer generated time series)

Empirical example: US "natural rate"

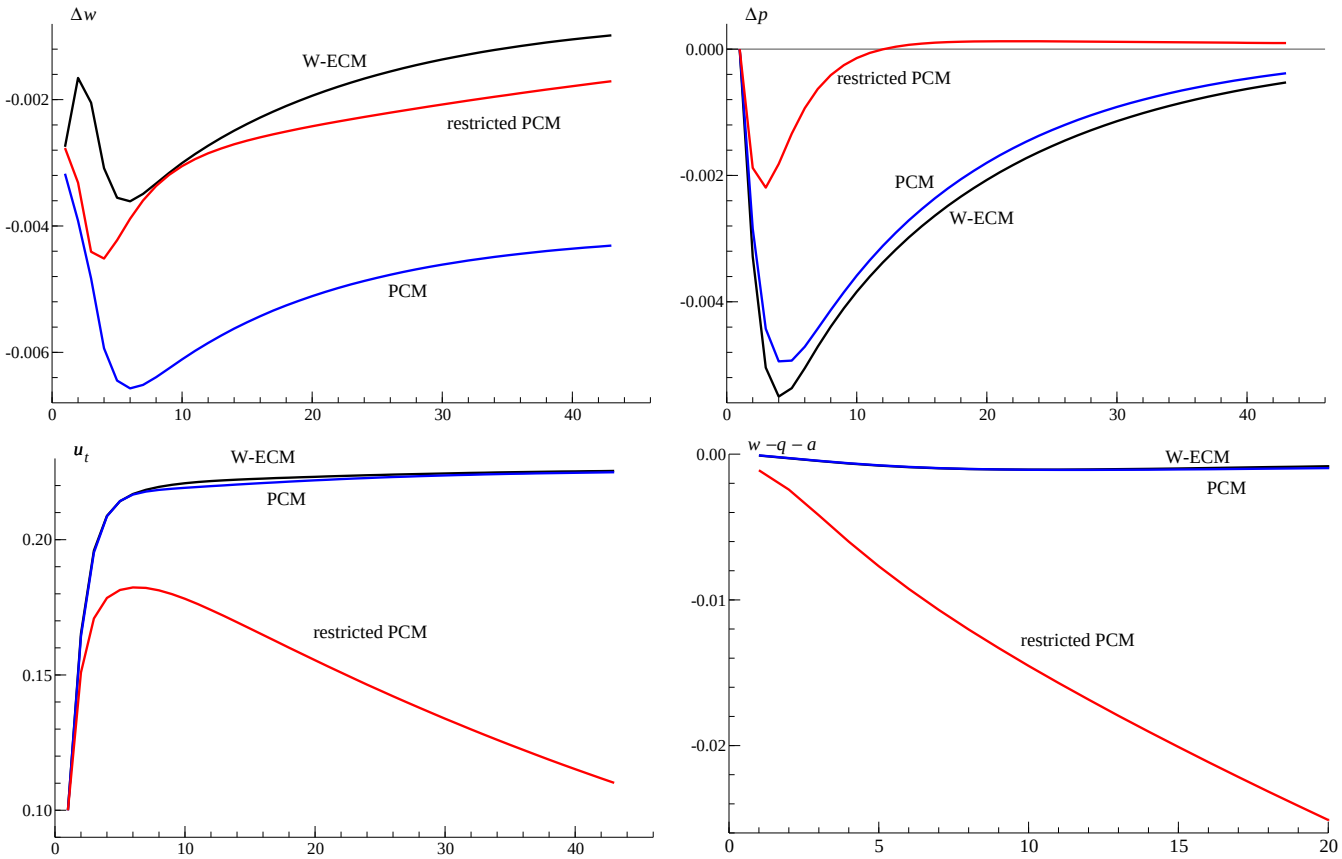
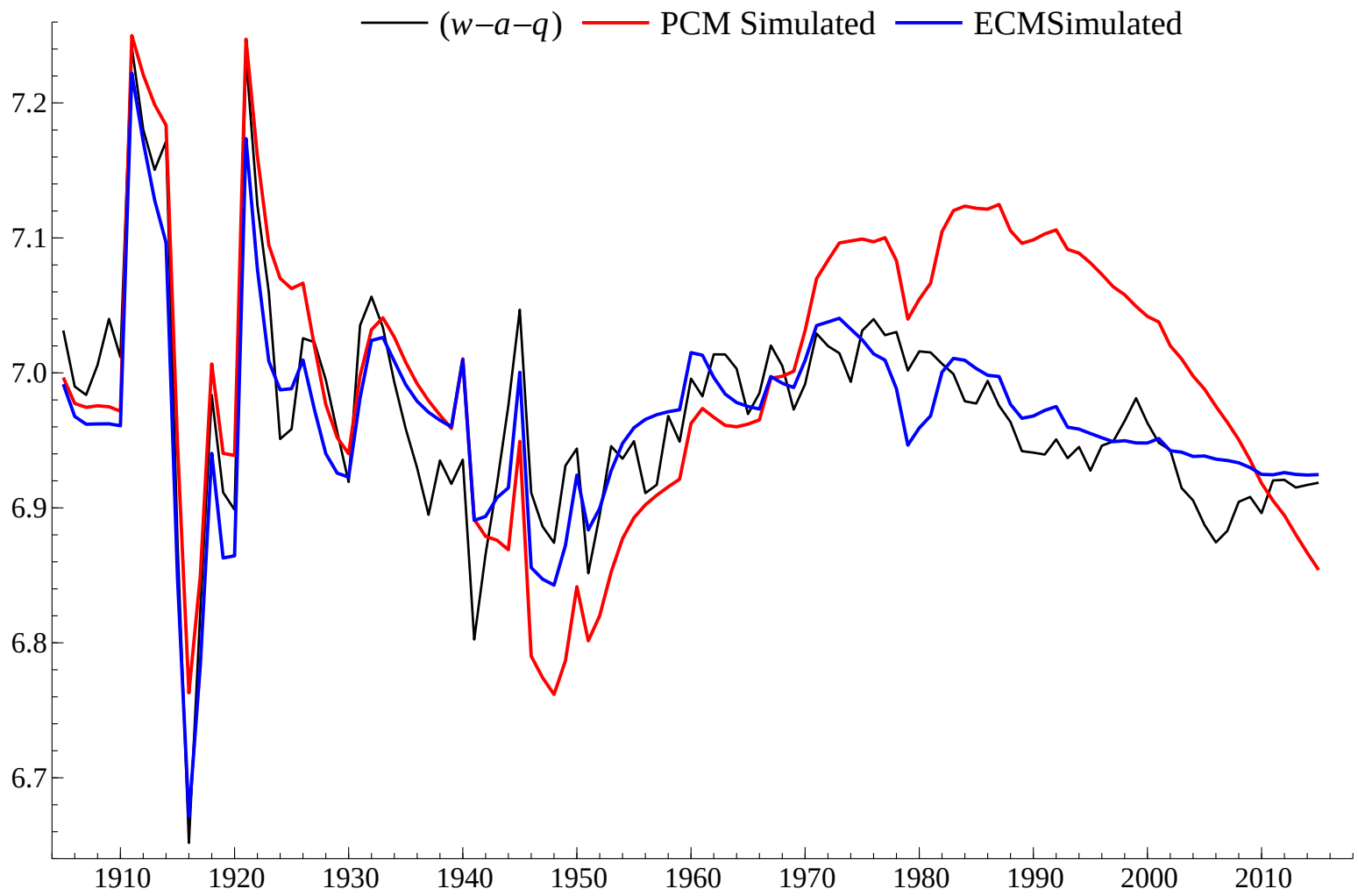


Figure 3: Dynamic multipliers of the econometric models PCM, W-ECM, and the restricted PCM, to a permanent exogenous 0.5 reduction in the unemployment percentage.

Extended equilibrium correction

- The close approximation of PCM response to WP-ECM reflects that equilibrium correction is a system property,
- *Extended equilibrium correction* is the phenomenon that adjustments can take place elsewhere in the system than just in wage-price module.
- rPCM in the picture shows that when extended equilibrium correction is *restricted*, the PCM solution stands out more clearly from WP-ECM

Empirical example: Norwegian wage-share in the long historical perspective



The importance of wage setting shows up in the solutions

- NPCM and WP-ECM have different solutions in general
- But not everything hinges of wage-price setting: Extended equilibrium correction (elsewhere in the economy) can counteract the differences.
- Other properties of models are closely connected to their solution:
  - Dynamic multipliers (US example above).
  - Model based forecasts.
  - Simulated stylized facts'
  - Optimal policies

  hence will therefore also be different, but by how much musst be analysed "per case".

Forecasts from WP-ECM and PCM

- The forecasting function for a variable in a dynamic system, has a *glide path* interpretation.
- It's origin is an observed starting point, and the end point of the glide path is the long-run mean (*ie* mathematical expectation of the variable).
- The glide path of linear models is continuous between the starting point and the end point, but it is not monotonous in general.
- Illustrate using the notation of the model typology (closed economy)

$$\Delta w_t = c_w + \pi_w \Delta p_t + \tau_w \Delta a_t - \beta_w ws_{t-1} - \sigma_w u_t + \varepsilon_{wt} \quad (7)$$

$$\Delta p_t = c_p + \tau_p (\Delta w_t - \Delta a_t) + \beta_p ws_{t-1} + \varepsilon_{qt} \quad (8)$$

$$u_t = c_u + \varrho ws_{t-1} + \alpha u_{t-1} + \varepsilon_{ut} \quad (9)$$

$$ws_{T+H}^{\text{WP-ECMf}} \underset{H\longrightarrow\infty}{\longrightarrow} \frac{(c_w + (\pi_w - 1)c_p - \sigma_w c_u - g_a)}{-\{(\pi_w - 1)\beta_p - \beta_w - \sigma_w \varrho\}} \tag{10}$$

$$ws_{T+H}^{\text{PCMf}} \underset{H\longrightarrow\infty}{\longrightarrow} \frac{(c_w + (\pi_w - 1)c_p - \sigma_w c_u - g_a)}{\sigma_w \varrho}. \tag{11}$$

and for the unemployment forecasts:

$$u_{T+H}^{mf} = c_u + \varrho ws_{T+H}^{mf} \tag{12}$$

and hence $u_{T+H}^{\text{WP-ECMf}} \neq u_{T+H}^{\text{PCMf}}$ also for the rate of unemployment. For the PCM specifically, we get:

$$u_{T+H}^{\text{PCMf}} \underset{H\longrightarrow\infty}{\longrightarrow} \frac{(c_w + (\pi_w - 1)c_p - g_a)}{\sigma_w} \tag{13}$$

i.e. the NAIRU rate above. In the case of vertical wage PCM ($\pi_w = 1$):

$$u_{T+H}^{\text{PCMf}} \underset{H\longrightarrow\infty}{\longrightarrow} \frac{(c_w - g_a)}{\sigma_w}. \tag{14}$$

a) The New Keynesian Phillips curve

The price version of the NPC, Galí and Gertler (1999) is defined as:

$$\Delta p_t = c_p + \underset{>0}{\pi_p^f} E_t[\Delta p_{t+1}] + \underset{\geq 0}{\pi_p^b} \Delta p_{t-1} + \underset{>0}{\beta_p} ws_t + \epsilon_{p,t}, \tag{15}$$

Process for the ws:

$$ws_t = c_{w0} + c_{w1} ws_{t-1} + c_{w2} ws_{t-2} + \varepsilon_{ws,t}, \tag{16}$$

Solution equation for Δp_t:

$$\Delta p_t = b_{p0} + b_{p1} \Delta p_{t-1} + b_{p2} ws_t + b_{p3} ws_{t-1} + \varepsilon_{p,t} \tag{17}$$

In terms of econometrics it is a ARDL equation, with pre-determined right-hand-side variables (based on the assumptions of the model).

b) The New Keynesian Wage Phillips curve

The wage-NKPC, due to Galí (2011) (with error term added) is:

$$\Delta w_t = c_w + \underset{>0}{\pi_w^f} E_t[\Delta w_{t+1}] + \underset{\geq 0}{\pi_w^b} \Delta \bar{\pi}_{t-1} + \underset{>0}{f} u_t + \epsilon_{w,t}, \tag{18}$$

Process for the u:

$$u_t = c_{u0} + c_{u1} u_{t-1} + c_{u2} u_{t-2} + \varepsilon_{u,t}, \tag{19}$$

The solution for Δw_t, given (18) and (19) takes the form:

$$\Delta w_t = b_{w0} + b_{w1} \Delta \bar{\pi}_{t-1} + b_{w3} u_t + b_{w3} u_{t-1} + \varepsilon_{w,t}. \tag{20}$$

another ARDL equation.

c) *A NKPCM model of wage and price dynamics* Collecting equations we can formulate a NKPCM-system:

$$\begin{aligned}
\Delta p_t &= b_{p0} + b_{p1}\Delta p_{t-1} + b_{p2} ws_t + b_{p3} ws_{t-1} + \varepsilon_{p,t}, && (21)\\
\Delta w_t &= b_{w0} + b_{w1}\Delta \bar{\pi}_{t-1} + b_{w3} u_t + b_{w3} u_{t-1} + \varepsilon_{w,t}, && (22)\\
ws_t &= \Delta w_t - \Delta p_t - \Delta a_t + ws_t && (23)\\
\bar{\pi}_t &= 0.25(\Delta p_t + \Delta p_{t-1} + \Delta p_{t-2} + \Delta p_{t-3}) && (24)
\end{aligned}$$

where the two last equations are identities that help close this model of the supply side. (24) is used by Galí in some of the reported estimates.

As an illustration, we report an estimated (21) using the data and sample period (1960(1)-1997(4)) in Galí and Gertler (1999):

$$\Delta p = \underset{(0.0398)}{0.8732}\ \Delta p_{t-1} + \underset{(0.000447)}{0.00122} + \underset{(0.028)}{0.06879}\ \Delta ws_t + \underset{(0.0154)}{0.0227}\ ws_{t-1}$$

- The puzzling result is that the coefficient of ws_{t-1} (i.e., $(d_{p2} + d_{p3})$) is insignificant: t-value 1.5.
- This problem (weak forcing variable), does not go away with change in estimation method.
- (22) does better, which is not surprising.

Some conclusions

- All three model types are equilibrium correction models
- All models generate neutral unemployment (steady state) rates and wage-shares
- Only in a restricted PCM case are the neutral rate the same as the textbook natural rate
- The NKPCM is another particular special case of an equilibrium correction model.
- Forecasts will have glide-paths for all models—but still differences in solution are reflected in the forecasts
- All forecasts are vulnerable to structural breaks near starting point and in post-forecast equilibria