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Resumé

Sammenlignet med tidligere årtier har lønstigningstakten i Danmark været afdæmpet siden midten af 1990'erne givet det pres, der efterhånden opstod på arbejdsmarkedet. Papiret beskriver de senere års ændringer på arbejdsmarkedet, herunder arbejdsmarkedsreformerne og decentraliseringen af løndannelsen, og gennemfører en empirisk analyse af lønudviklingen i Danmark fra 1975 til 2007. Resultaterne indikerer, at den danske lønudvikling på langt sigt kan beskrives ved en reallønskurve. På kort sigt synes en lønrelation med fejlkorrektion mod denne reallønskurve at klare sig bedre end en simpel phillipskurve.

Wage Dynamics in Denmark*

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Abstract

Compared with the previous decades the rate of wage increase in Denmark has been subdued since the mid-1990s, given the pressure that gradually arose in the labour market. The paper describes changes in the labour market in recent years, including labour-market reforms and decentralisation of wage formation, and an empirical analysis of wage development in Denmark from 1975 to 2007 is performed. The results indicate that in the long term Danish wage development can be described by a real-wage curve. In the short term a wage equation with error correction towards this real-wage curve seems to outperform a simple Phillips curve.

*Comments from seminar participants at the University of Copenhagen and at Danmarks Nationalbank are gratefully acknowledged. The views expressed are those of the author and do not necessarily reflect the views of Danmarks Nationalbank.

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1 Introduction

Wage formation is key to the development in prices and costs. The reason is that in many firms labour is the most important production factor and the development in firms' production costs is therefore highly dependent on wage development. Through their impact on costs, wages also become an important element in price setting.

In an open economy like Denmark, wages also play a key role in relation to competitiveness. Higher wage increases than abroad lead to deteriorating competitiveness unless the excess wage increase is based on more favourable productivity development. Due to its impact on competitiveness, wage formation is also potentially important in relation to reducing cyclical fluctuations in economies with substantial foreign trade. The mechanism implies that deteriorating competitiveness resulting from excessive wage increases has an adverse impact on exports and increases unemployment. Declining pressures on the labour market gradually lead to lower wage increases than abroad, thereby restoring competitiveness and equilibrium in the economy.

In recent years, globalisation has increased cross-border trade in goods and services and led to fiercer price competition. Stronger competition has put further pressure on business enterprises to streamline their production and keep costs down, so globalisation has also had an impact on wage formation. The integration of China and other countries into the international division of work has contributed to expanding the global labour force, and at the same time labour-market integration has improved, especially in Europe. There has also been a large influx of foreign labour to the Danish labour market in the latest upswing, cf. Pedersen and Riishøj (2008). Because of these changes, the development in wages and unemployment abroad is likely to have a greater impact on wage formation in Denmark than it did previously.

The last 20 years have seen structural labour-market changes in Denmark that have resulted from politically determined labour-market reforms as well as agreements between the social partners. The labour-market reforms have increased the incentive to seek

employment since the mid-1990s due to tightening of unemployment benefit structures and increased use of activation schemes. A significant development in the system of agreements was the trend in the early 1990s towards more decentralised wage bargaining, as a result of which wages are increasingly determined at enterprise level.

The labour-market reforms have lowered structural unemployment, i.e. the unemployment level that is compatible with stable wage and price developments a few years ahead. At the same time, actual unemployment decreased substantially from the peak of around 350,000 persons in 1993 to the latest trough of around 50,000 in 2008. The substantial drop in unemployment occurred without the rate of wage increase rising as much as warranted by estimated wage models. The deviations have been permanent, and the previous wage models can almost be said to have broken down. From a modelling perspective, there are several possible solutions to the problems. One possibility is to allow a break in the relationship between wages and unemployment, e.g. in connection with the labour-market reforms implemented, the decentralisation of wage bargaining or globalisation. Another strategy is to search for relevant, but so far omitted variables. Alternatively, it might be considered whether developments are better explained using other models.

The paper presents an empirical analysis of wage development in Denmark from 1975 to 2007. Models based on wage bargaining, a Phillips curve and the Scandinavian model of inflation will be considered. The results indicate that in the long term Danish wage development can be described by a real-wage curve.

A wage model to explain short-term wage changes is also estimated. All other things being equal, the rate of wage increase tends to be lower if wages have increased too much in relation to the long-term equilibrium level resulting from the real-wage curve. The estimated adjustment coefficient is modest, however, so the movement towards the equilibrium wage takes some time. In the short term, wage increases are also dependent on changes in consumer and producer prices and on changes in agreed working hours.

The paper is structured as follows. Section 2 briefly describes the recent development in the Danish labour market and the choice of wage measure used in the paper. In section 3 the three wage models are presented, and section 4 looks at the data. Section 5 contains a cointegration analysis followed by estimation of a dynamic wage equation in section 6. The last section offers a few concluding remarks.

2 Wage development and the labour market

In a longer-term perspective, wage growth has been subdued since the mid-1990s in light of the growing labour-market pressure, cf. Chart 1. Calculated on a quarterly basis, the annual rate of wage increase in industry was thus between 2.5 and 5.0 per cent. The rate of price increase in the same period was low and stable, and consequently real wages in industry rose year by year. Wage increases in the public sector have been at a similar level to those in industry, but have fluctuated a bit more. The close link between wage increases in the public and private sectors should also be viewed in the light of the regulation scheme under the public-sector collective agreements, the purpose of which is to contribute to parallel wage development.

Traditionally, empirical analyses focus on wages in manufacturing industry, where the best long-term data is available. Industry's share of the economy is under 20 per cent and slightly declining, however, and it might therefore be more natural to examine wages in the private sector overall. As shown in Chart 2, wages in the private sector continue to follow wages in industry very closely, and the paper will therefore consider wage development in industry – more specifically Statistics Denmark's wage index for industry.

The Danish labour market has undergone a number of reforms since the mid-1990s. The maximum unemployment benefit entitlement period was gradually reduced to stand at four years at the end of the period under review, and it is no longer possible to re-

gain the right to unemployment benefits by activation. The "passive" period before an activation process is initiated has been significantly reduced. Requirements for the unemployed to be available for work have been tightened on an ongoing basis, and sanctions have been made more stringent. Most recipients of cash benefits are now subject to the same availability rules as unemployment benefit recipients. Special measures have been implemented for unemployed persons under the age of 25, including a lower benefit level, and this has led to a significant drop in youth unemployment. Finally, unemployment benefits have not increased at the same rate as wages, thus reducing the replacement ratio in the event of unemployment. As a result of the reforms, structural unemployment, i.e. the level of unemployment that is compatible with a stable development in inflation over a few years, is estimated to have declined by more than half since 1995, cf. the Ministry of Finance (2009).

In addition to the changes in the regulatory framework, the system of bargaining between the social partners has also evolved. With regard to wage formation, decentralisation of the determination of wages is particularly important. There has been a trend away from the standard wage system, whereby hourly wages are determined centrally in connection with collective bargaining, towards the minimum-wage/minimum-pay system with collective agreements stipulating only a minimum rate and the final hourly wage being negotiated at the individual firm level. Industry has a long-standing tradition for annual wage bargaining at firm level.

The average duration of collective agreements has increased from the standard two years up until the mid-1990s to three years. This should presumably be viewed in the light of increasing price stability and the trend towards the minimum-wage/minimum-pay system. Due to the possibility of wage regulation within the agreement period, the longer duration of the agreements does not necessarily reduce flexibility.

Labour-market structures have improved as a result of the reforms, and the Danish labour market is seen to be relatively flexible compared with those of other European

countries. Comparisons of countries show that institutional conditions differ considerably, cf. the questionnaire survey in Du Caju et al. (2008). Developments since the mid-1990s have not changed this, although a general trend towards more decentralised wage bargaining can be seen. The wage bargaining level is among the most significant structural differences between the countries, as bargaining takes place centrally in some countries and at sector or enterprise level in others. The rate of employee unionisation, which is relatively high in Denmark, varies considerably from country to country, but even so, a large proportion of employees are covered by a collective agreement in most European countries. This is often due to the extension of collective agreements to include unorganised employers and non-union employees. In many countries the average duration of the agreements is shorter than in Denmark, and unlike Denmark, almost half of the countries in the survey apply some sort of indexation of wages to prices.

3 Theoretical framework

Over time several approaches to modelling wages have been suggested in the literature. Here we follow Bårdsen et al. (2005) in considering three possibilities: wage bargaining, the Phillips curve and the Scandinavian model of inflation. In the following, a brief outline of the models is given, and the associated wage equations are derived.

3.1 Wage bargaining

We consider a simple theoretical model of decentralised wage bargaining and monopolistic competition building on e.g. Layard et al. (2005). A large number of firms are assumed to face downward-sloping demand curves. The firms are price-setters and labour is the only variable factor of production. We assume that there is constant returns to scale in

production and that firms are identical. A firm's profits are given by

$$\Pi = Y\left(Q - \frac{W}{A}\right), \tag{1}$$

where Y is production, Q is the price set by the firm, W is the wage and A is average labour productivity. Solving the firm's optimisation problems leads to the following price-setting equation

$$Q = \frac{\varepsilon}{\varepsilon - 1}\frac{W}{A}, \tag{2}$$

where $\varepsilon = -Y'_Q Q/Y > 1$ is the absolute value of the elasticity of the firm's demand with respect to its own price.

Wages are bargained between unions and employers, and we assume that the result is given by the maximum of the Nash product

$$\mathcal{N} = (v - v_0)^{\sigma}\, \pi^{1-\sigma}, \tag{3}$$

where v is union utility, v_0 is the fall-back union utility and $\pi = \Pi/Q$ is real profits. The fall-back profit for firms is zero.[1] σ measures the relative bargaining power of unions.

Union utility depends on the consumer real wage of a worker employed at the firm

$$v = v\left(W/P, Z_v\right),\ v'_{W/P} > 0, \tag{4}$$

where P is the consumer price index, and Z_v represents other factors in union preferences. The fall-back union utility is the utility workers can obtain outside the firm which depends

[1] If firms have fixed costs that must be paid also in the event of a conflict, we can think of π as profits net of fixed costs.

on the overall real-wage level in the economy and the rate of unemployment

$$v_0 = v_0\left(\overline{W}/P, U\right),\ v'_{0\overline{W}/P} > 0,\ v'_{0U} < 0, \tag{5}$$

where $\overline{W}$ is the average level of nominal wages. The Nash product thus becomes

$$\begin{aligned} \mathcal{N} &= \left\{v\left(W/P, Z_v\right) - v_0\left(\overline{W}/P, U\right)\right\}^{\sigma} \left\{Y\left(1 - W/(AQ)\right)\right\}^{1-\sigma} \\ &= \left\{v\left(W_q/P_q, Z_v\right) - v_0\left(\overline{W}/P, U\right)\right\}^{\sigma} \left\{Y\left(1 - W_q/A\right)\right\}^{1-\sigma}, \end{aligned} \tag{6}$$

where $W_q = W/Q$ is the producer real wage and $P_q = P/Q$ is the wedge between the consumer and producer real wage.

Maximising the Nash product with respect to the producer real wage and imposing symmetry between firms $\left(\overline{W} = W\right)$ we find the following equilibrium relationship

$$\sigma \frac{v'_{W/P}\left(W_q/P_q, Z_v\right) P_q^{-1}}{v\left(W_q/P_q, Z_v\right) - v_0\left(W_q/P_q, U\right)} = (1-\sigma)\frac{1/A}{\left(1 - W_q/A\right)}. \tag{7}$$

This equation implicitly defines the bargained real wage W_q^b as a function of A, Z_v, σ, P_q, and U

$$W_q^b = F\left(A, Z_v, \sigma, P_q, U\right). \tag{8}$$

Log-linearisation leads to

$$w_{q,t}^b = m_{b,t} + \omega p_{q,t} - \varpi u_t,\ 0 \leq \omega \leq 1,\ \varpi \geq 0, \tag{9}$$

where $m_{b,t}$ depends on A, Z_ν and σ, all of which may change over time. We assume that the wedge coefficient ω is positive, but below one, and that the bargained wage depends negatively on the unemployment rate, cf. Rødseth (2000) for a discussion.

In the following we shall extract productivity from $m_{b,t}$ to arrive at

$$w^b_{q,t} = m_b + \iota a_t + \omega p_{q,t} - \varpi u_t,\ 0 < \iota \leq 1,\ 0 \leq \omega \leq 1,\ \varpi \geq 0, \tag{10}$$

where m_b now depends on Z_v and σ, which are assumed to be constant over time. The cointegrating wage equation is written as

$$w_{q,t} = m_b + \iota a_t + \omega p_{q,t} - \varpi u_t + ecm_{\,b,t}, \tag{11}$$

where $ecm_{b,t} = w_{q,t} - w^b_{q,t} \sim \mathrm{I}(0)$.

Assuming that there is error correction in wages, a dynamic wage equation may be written as

$$\Delta w_t = c_w + \psi_{wp}\Delta p_t + \psi_{wq}\Delta q_t - \theta_w \left(w_{q,t} - m_b - \iota a_t - \omega p_{q,t} + \varpi u_t\right) + \varepsilon_{w,t}, \tag{12}$$

where we allow for short-run influences of changes in consumer and producer prices on wages.

3.2 Phillips curve

The Phillips curve became a popular framework for modelling wages following Phillips' (1958) finding of an empirical relationship between the rate of wage increase and the level of unemployment in the UK. Wage increases tended to be low when unemployment was high and vice versa. A simple interpretation is that high unemployment leads to excess supply of labour which in turn gives a downward pressure on wages.

A prominent extension of the original Phillips curve is the inclusion of the rate of price change as an explanatory variable, a formulation known as the expectations-augmented Phillips curve. One argument for the extension is that higher inflation increases workers' cost of living and leads to higher wage claims. Lipsey (1960) showed that including the

inflation rate in the regression improved the fit of the Phillips curve.

It is open to discussion whether the historical, the current or the expected future price rises should be included in the Phillips curve. In an empirical perspective this is less important, however – particularly when inflation is relatively stable. In the absence of good statistics on expected inflation, current and historical inflation rates often have to be used in any case.

The focus on wage *changes* means that the Phillips curve as such does not determine the wage level at a specific unemployment level. This is considered a weakness in the model, but in a larger economic model the wage level does not have to be undetermined. A low wage level leads to strong competitiveness, export growth, increased employment and reduced unemployment. At a lower rate of unemployment, wage growth is pushed up through the Phillips curve, thereby increasing the wage level until the competitive edge is eliminated. We return to this issue below.

The relationship between wage growth and unemployment has given rise to much discussion over the years, due not least to its impact on economic policy options. When introduced, the Phillips curve was interpreted to the effect that economic policy faced a tradeoff between unemployment and wage and price increases. By stimulating demand it was possible to reduce unemployment through economic-policy measures, but at the cost of higher wage and price increases.

From the late 1960s, economists began to realise that while it might be possible to reduce unemployment in the short term by stimulating demand, the effect was not permanent. In the long term, price increases will be fully reflected in wage increases (homogeneity), resulting in a vertical Phillips curve. As a result, the trade-off between inflation and unemployment disappears – in the long term, unemployment is the same regardless of the rate of inflation. The "natural rate" of unemployment is defined as the long-term rate of unemployment corresponding to the vertical Phillips curve, cf. Friedman (1968) and Phelps (1968).

A simple formulation of the Phillips curve is

$$\Delta w_t = c_w + \psi_{wp}\Delta p_t + \psi_{wq}\Delta q_t - \varpi u_t + \varepsilon_{w,t}. \tag{13}$$

The Phillips curve is a simple dynamic model and does not imply any long-run relationship for wages. As noted above, however, in the long run a stable rate of unemployment is implied. As a simple way of obtaining a complete system, an equation for the unemployment rate may be added

$$\Delta u_t = c_u - \kappa u_{t-1} + \nu\left(w_{q,t-1} - a_{t-1}\right) - \lambda z_{u,t},\ 0 < \kappa < 1,\ \nu > 0,\ \lambda \geq o \tag{14}$$

where z_u represents other factors which lower the rate of unemployment. The idea underlying this equation is that a high wage share implies low profitability which leads to higher unemployment. In the Phillips curve framework equilibrium correction takes place outside the wage equation, e.g. in the unemployment equation, and without this mechanism the wage share would be dynamically unstable. The unemployment equation captures in a simple way the argument from above that the level of wages is determined outside the Phillips curve equation.

3.3 Scandinavian model of inflation (main-course model)

The main-course model stresses the importance of price impulses from abroad for inflation in an open economy. The two-sector version of the model in Aukrust (1977) features a sector exposed to foreign competition which takes prices as given. Together with productivity foreign prices trace out a path – a main course – for wages. While deviations from the main course is possible in the short run, in the long run wages in the exposed sector must adjust to the main course, ensuring a "normal" level of profit in that sector. Wages in the other (sheltered) sector is, in turn, assumed to follow wages in the exposed sector.

Focusing on the exposed sector, the main-course proposition implies that the wage share is stationary

$$w_{q,t} - a_t \sim \mathrm{I}(0). \tag{15}$$

Bårdsen et al. (2005) consider an extension of the model in which the mean wage share is not constant over time, but may depend on the rate of unemployment

$$w_{q,t} - a_t + \varpi u_t \sim \mathrm{I}(0). \tag{16}$$

To be consistent with the main course model, the unemployment rate must be I(0). Other variables that explain shifts in the mean of the wage share could be included.

According to Aukrust, correction of a deviation from the main course takes place through wages. Wage negotiations is mentioned as one possible corrective mechanism. High profits (low wage share) leads to higher wage claims that are more likely to be accepted by the employers, so that the wage share is pushed towards its equilibrium level. Economic policy seeking to restore international competitiveness in an economy where wages have risen above the main course may be another mechanism through which wage share deviations are corrected. Finally, market forces give a third corrective mechanism as shifts in world demand from the goods produced in a high-wage, high-price country towards lower priced foreign goods leads to lower labour demand and lower wages in the high-wage country.

A dynamic wage equation with equilibrium correction toward the extended main-course equilibrium wage share (16) may be written as

$$\Delta w_t = c_w + \psi_{wp}\Delta p_t + \psi_{wq}\Delta q_t - \theta_w\left(w_{q,t} - m_b - a_t + \varpi u_t\right) + \varepsilon_{w,t}, \tag{17}$$

where m_b is the mean of the cointegration relationship.

4 Data

The data is taken from the database of the Nationalbank's quarterly macroeconomic model, MONA. We consider a sample from 1975:1 to 2007:4. The real consumer wage, the real producer wage and the wedge include tax terms.

Based on the ADF tests in Table 1[2] the first difference of most of the variables appear stationary, consistent with the levels being integrated of order one. The ADF tests on levels indicate that the wage and price levels could be considered stationary. However, given the results from the test on the first differences and the graphs in Charts 3a and 3b, we will take wages and prices to be integrated of order one in the following.[3] Note that the wage share (measured using both consumer and producer prices) seems to be integrated of order one, which is evidence against the simple main-course model. We will return to the empirical validity of extended main-course models below.

5 Cointegration analysis

The empirical analysis is carried out in a cointegrated VAR framework so that both the short- and long-run relationships discussed in the theoretical overview of the previous section can be investigated. A model specification that is sufficiently general for our purposes may in error-correction form be written as

$$\Delta Y_t = \Pi Y_{t-1}^* + \sum_{i=1}^{k-1} A_i \Delta Y_{t-i} + BZ_t + \varepsilon_t, \tag{18}$$

where Y_t contains the endogenous I(1) variables, Z_t contains non-modelled variables, Y_t^* is Y_t together with the restriced non-modelled variables, k is the lag length of the VAR,

[2] * (**) denotes significance at the 5 (1) per cent level, respectively.

[3] In view of the zero-one range for the unemployment rate, the tax rates, the replacement ratio and the wage shares it is natural to think of these as stationary variables. But we choose not to impose this as an assumption at this stage.

and it is assumed that $\varepsilon_t \sim i.i.d.\ N(0, \Omega)$. The first term is the long-run or cointegrating relationships, where Π has reduced rank and can be decomposed as $\Pi = \alpha\beta'$, where β consists of the cointegrating vectors and α holds the loading coefficients. The short-run dynamics is described by the autoregressive elements in the second term, while the third term holds non-modelled conditioning variables and deterministic terms.

We consider a specification of the model (18) similar to that set up by Hansen (1998) to analyse wage determination in Denmark. The model is sufficiently general to be consistent with the three theories discussed above. At the outset, five variables are taken to be endogenous

$$Y_t = (w_t, a_t, p_t, U_t, p_{q,t})', \tag{19}$$

where w denotes wages, a labour productivity, p consumer prices, U the rate of unemployment and p_q the wedge betwen consumer and producer real wages.[4] The non-modelled variables include a constant, the change in the contractual hours worked, h, current and lagged changes in income tax rates and payroll tax rates, t_i and t_p, the current income tax rate as well as the current and lagged replacement ratio, r. The current income tax rate and replacement ratio are restricted to the cointegrating space, while the other variables are left unrestricted. In sum,

$$\begin{aligned} Z_t &= (Z_t^u, Z_t^r)' \text{ are non-modelled with} \\ Z_t^u &= (\text{constant}, \Delta h_t, \Delta t_{i,t}, \Delta t_{p,t}, \Delta t_{i,t-1}, \Delta t_{p,t-1}, \\ &\quad r_{t-1}, \ldots, r_{t-4}) \text{ unrestricted}, \\ Z_t^r &= (t_{i,t}, r_t) \text{ restricted}. \end{aligned} \tag{20}$$

The model has many similarities with that analysed by Bårdsen et al. (2005, section 5.5). However, the endogenous price variable is consumer rather than producer prices,

[4] Lower-case letters denote logs of the corresponding capital letters.

and the model treats the replacement ratio as exogenous from the outset and has a larger set of conditioning variables.

A lag length of four is chosen, and the model generally passes standard tests for misspecification, cf. Table 2. There are signs of ARCH in the error term of the price equation. Normality of the error term in the unemployment equation and in the complete model is also rejected, but this seems to be due to an outlier.[5]

The test for the cointegration rank is not clearcut, cf. Table 3,[6] and we will look at both one and two cointegrating relations.

Assuming first a cointegration rank of one, we find the following long-run relationship

$$w_t = m_w + 1.59p_t + 0.32a_t - 1.97U_t - 2.68p_{q,t} - 0.57r_t - 2.49t_{i,t} + ecm_t, \tag{21}$$

when we normalise on w and let ecm_t denote the equilibrium correction term. This relationship could represent either a long-run price equation or a long-run wage equation, although the negative coefficient with respect to unemployment suggests that it is a wage equation. Restricting the elasticities with respect to the consumer price and productivity to one, we can write the long-run relationship in terms of $w - p - a$

$$w_t - p_t - a_t = m_w - 1.59U_t - 1.54p_{q,t} + 0.94r_t - 0.72t_{i,t} + ecm_t. \tag{22}$$

A joint test of the restrictions give $\chi^2(2) = 6.4310$ [0.0401] (P-value in square brackets). Note that the elasticity with respect to the replacement ratio has changed sign and that the elasticities with respect to the wedge and the income tax rate have declined

[5] Introducing a step dummy variable that takes on the value 1 in the 4th quarter of 1995, we get an insignificant test statistic both for the unemployment equation and for the complete model. In the following we do not include this dummy variable.

[6] As a robustness check, the test for cointegration rank has also been performed with a restricted trend added to the model as suggested by Detremescu, Lütkepohl and Saikkonen (2009). The results are qualitatively unchanged.

substantially. It turns out to be possible to omit the income tax rate[7] and restrict the elasticity of the wedge to one, so that we obtain

$$w_t - p_t - a_t = m_w - p_{q,t} - 1.19U_t + 0.85r_t + ecm_t, \tag{23}$$

and the restrictions are not rejected ($\chi^2(4) = 6.9165$ [0.1404]). This long-run relationship takes the form of a real-wage curve, consistent with e.g. a wage bargaining model. It could also be consistent with an extended main-course model, if the unit coefficient on the wedge variable allows us to reparameterise the relationship in terms of the wage share $w - q - a$ without any wedge term. Taking the unemployment rate to be integrated of order one as we have done so far is, however, not consistent with the main-course model.

The elasticity with respect to the unemployment rate is a semi-elasticity as the unemployment rate is not in logs. To make it comparable to the true elasticity found in other studies, one may multiply it by the average unemployment rate in the sample period 0.070 to obtain an estimate of 0.083, which is not too far from the 0.1 elasticity often considered a benchmark following Blanchflower and Oswald (1994).

In a study of Danish wage formation Knudsen (1992) found a cointegrating relation involving only the unemployment rate and the replacement ratio.[8] Restricting the coefficients of the other variables in the long-run relation to zero gives $\chi^2(5) = 12.770$ [0.0256], so that this long-run relationship no longer seems to be supported by the data.[9]

Turning to the issue of weak exogeneity, we can now write the system in simplified

[7] Hansen (1998) appears to restrict the long-run elasticity with respect to the income tax rate to one. When testing this restriction jointly with the other restricition we find that a unit long-run elasticity is not accepted by the data in our sample (P-value 0.02)

[8] Hansen (1998) confirmed the validity of this cointegration relation on a sample ending in 1995.

[9] Also, the unemployment rate appears to be weakly exogenous. That goes against a Phillips-curve framework in which error correction in the rate of unemployment provides the equilibrating mechanism.

form as[10]

$$\begin{pmatrix} \Delta w_t \\ \Delta p_t \\ \Delta a_t \\ \Delta U_t \\ \Delta p_{q,t} \end{pmatrix} = \begin{pmatrix} -0.039\,(0.014) \\ -0.044\,(0.020) \\ 0.14\,(0.041) \\ 0.0055\,(0.0055) \\ -0.087\,(0.035) \end{pmatrix} * ecm_{t-1} + \ldots \tag{24}$$

There seems to be significant error correction in wages, productivity and the wedge, but not in unemployment or prices. Testing the two weak exogeneity restrictions leads to $\chi^2(2) = 4.3317$ [0.1147], implying that consumer prices and the unemployment rate may be considered weakly exogenous for the long-run parameters. A joint test of all six restrictions gives $\chi^2(6) = 11.126$ [0.0846] and the final cointegration relationship reads

$$w_t - p_t - a_t = m_w - p_{q,t} - 0.98U_t + 0.35r_t + ecm_t. \tag{25}$$

The estimates of the elasticities of the rate of unemployment and of the replacement ratio are relatively stable over time, cf. Chart 4. When compared to the ± 2 estimated standard errors, the replacement ratio has, however, been insignificant at times. The chart also shows that the overidentifying restrictions would not have been rejected on samples ending in 1997 and later.

Next we assume that there are two cointegrating relationships. We find the following normalised, but not identified, cointegration vectors

$$\begin{aligned} w_t &= m_w + 1.33p_t + 0.58a_t - 1.72U_t - 1.97p_{q,t} - 0.12r_t - 1.60t_{i,t} + ecm_{1,t}, \quad (26) \\ p_t &= m_p + 2.67w_t - 3.98a_t + 2.15U_t - 1.45p_{q,t} - 3.91r_t - 4.14t_{i,t} + ecm_{2,t}. \end{aligned}$$

Restrictions corresponding to one of the cointegrating vectors being the one identified

[10] Standard errors in parentheses.

above and the other cointegrating vector not affecting the wage equation are not rejected ($\chi^2(6) = 3.3141$ [0.7685]). Tests for weak exogeneity show that only the unemployment rate may be considered exogenous in the case of two cointegrating vectors. We note that in this case the above-mentioned cointegrating relation involving only unemployment and the replacement ratio is not rejected by the data ($\chi^2(4) = 9.1306$ [0.0579]). Identifying a real wage curve together with a Phillips curve at the same time is rejected by the data ($\chi^2(6) = 21.628$ [0.0014]), but it may nevertheless be of interest that the estimated loading factor in the wage equation is negative and significant for the real wage curve, while it is positive and insignificant for the Phillips curve.

All in all, the results seem to favor a real-wage curve as the best description of the long-run relationships in the data.

6 Dynamic wage model

In this section we seek to estimate single equation dynamic wage models taking into account the results from the cointegration analysis above. The stability of the estimated parameters is investigated together with the model's ability to forecast out-of-sample.

First, we look at the relative performance of wage equations based on a real wage curve and a Phillips curve, respectively. We start out with a general model in which quarterly wage changes are explained by lagged wage changes, changes in consumer prices, changes in producer prices and changes in the agreed working hours. The two types of wage models are allowed for by including the lagged level of unemployment (consistent with a Phillips curve) and the identified cointegrating relation found above (consistent with a real-wage curve). The general specification reads:

$$\Delta w_t = \alpha + \sum_i \delta_i \Delta w_{t-i} + \sum_j \beta_j \Delta p_{t-j} + \sum_k \beta_k \Delta q_{t-k} - \lambda \Delta h_t - \phi U_{t-1} - \chi ecm_{t-1} + e_t. \quad (27)$$

Estimating the equation by OLS using a general-to-specific procedure where insignificant variables are successively removed, we arrive at the following wage equation

$$\Delta w_t = -0.0023 + 0.28\Delta w_{t-3} + 0.17\Delta p_t + 0.26\Delta p_{t-2} + 0.071\Delta q_{t-1} - 0.97\Delta h_t - 0.041 ecm_{t-1}. \tag{28}$$

The model explains about 60 per cent of the variation in quarterly wage changes. The diagnostic tests generally look fine, except the test for normality of the errors and the RESET specification test, cf. Table 4.

The level of unemployment does not enter the final dynamic wage equation in contrast to the Phillips curve. Also, the presence of the wage share in the dynamic wage equation runs counter to the Phillips curve model. As expected from the analysis of the system above, there is significant error correction related to deviations from the real-wage curve. The adjustment coefficient is, however, small in absolute value implying that the adjustment to the long-run real wage through nominal wage changes is slow.[11] Changes in contractual working hours has a large and significant effect on the wage change. This result is standard in estimated Danish wage equations and is related to the fact that working-time reductions have usually been given with full wage compensation.

In the short run price increases are not fully transmitted to wages, but within two quarters after an equal increase in consumer and producer prices, 60 per cent of the increase is reflected in the wage, and after five quarters the wage response has risen to 80 per cent. The estimated less than full transmission of prices to wages must be seen in light of the low and stable inflation rate in most of the sample, where monetary policy at least since 1982 has operated under a fixed exchange rate regime. In the long run price increases are fully reflected in the nominal wage due to the error correction towards the long-run real-wage curve.

[11] According to the system results deviations from the real wage curve are also corrected by changes in productivity and the wedge.

Recursive estimation of the wage equation shows that the parameters are relatively stable after the mid-1990s, cf. Chart 5. However, the adjustment coefficient tends to decline somewhat in absolute value after 2000. The Chow tests do not identify any breaks in the last half of the sample.

7 Conclusion

Registered unemployment in Denmark has declined substantially since 1994 without wage increases rising correspondingly. This has challenged the use of simple Phillips curves as a model of Danish wage formation. In this paper, an empirical analysis of industrial sector wages since 1975 has considered whether a real wage curve or a main-course wage relation represents a useful alternative to the Phillips curve.

Generally, the results of the paper point to a real wage equation rather than a Phillips curve. In the cointegration analysis, a long-run relationship consistent with a real wage equation as in e.g. a wage-bargaining model was found. The relevance of deviations from this long-run relationship for wage changes in the short run was also confirmed in a single-equation analysis of quarterly wage changes. While the general specification of the dynamic wage equation to begin with also included the level of unemployment as in a Phillips curve, this term turned out to be insignificant and only the real wage error correction term appeared in the final specification.

The single-equation estimation results show that in the short run price increases are only partially reflected in wages. In the long run, error correction towards the real wage curve moves wages further towards the equilibrium wage share. However, as shown in the analysis of the system correction towards the equilibrium does not only involve wage adjustment but also changes in productivity and the wedge.

8 Appendix

The data is taken from the database of the Nationalbank's quarterly macroeconomic model, MONA. The time series are:

W: hourly wage rate, industrial worker[12]

P: private consumption deflator

Q: gross value added deflator, private non-farm sector

A: hourly productivity, private non-farm sector

U: unemployment

H: agreed working hours

R: average replacement ratio for unemployment benefits

T_i: average income tax rate

T_p: indirect labour costs, private non-farm sector.

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[12]Statistics Denmark has switched to the new industrial classification DB07. The data basis for used here is the previous industrial classification, DB03.

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10 Charts and tables

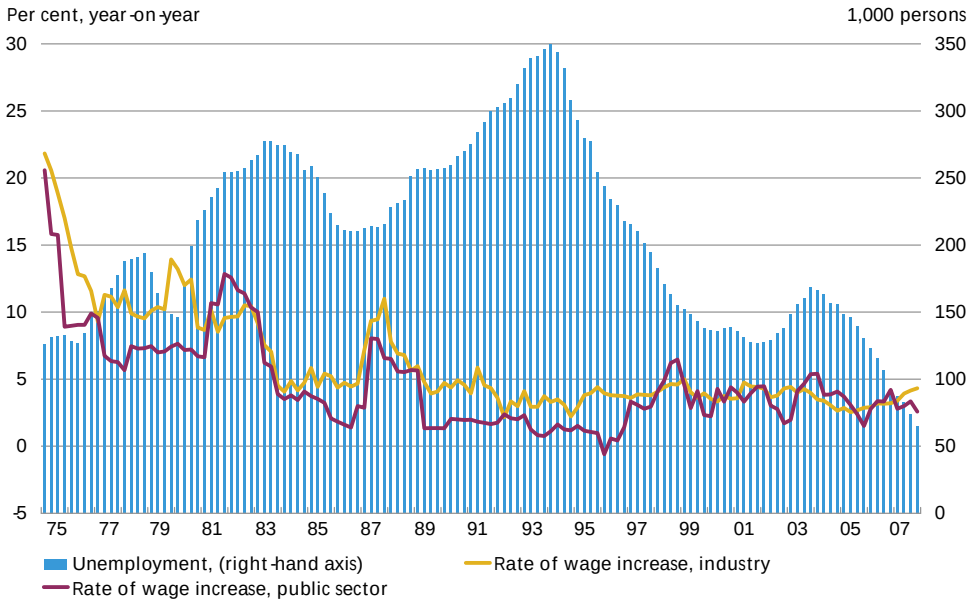

Chart 1: Rate of wage increase and unemployment, 1975-2007

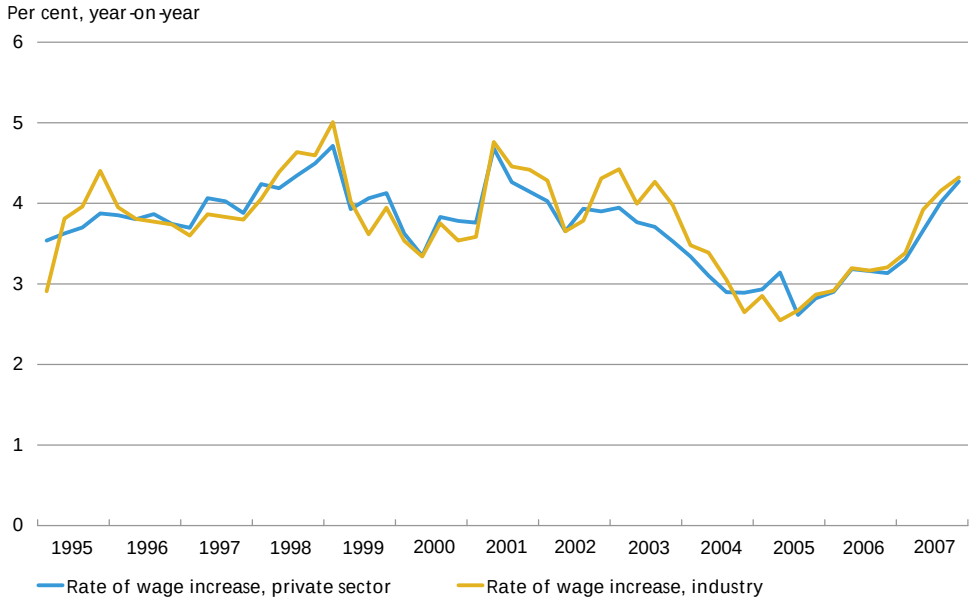

Chart 2: Rate of wage increase in industry and in the private sector, 1995-2007

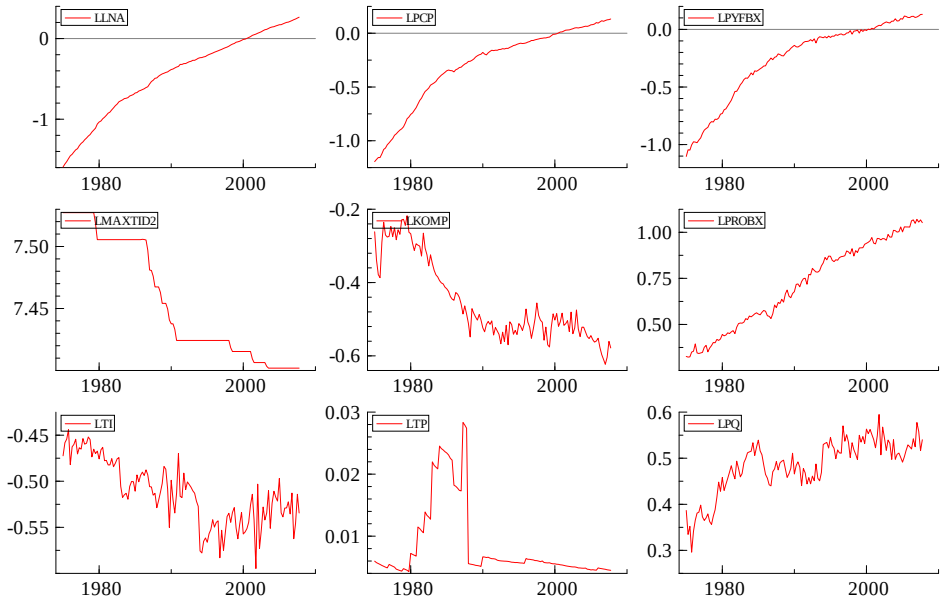

Chart 3a: Data

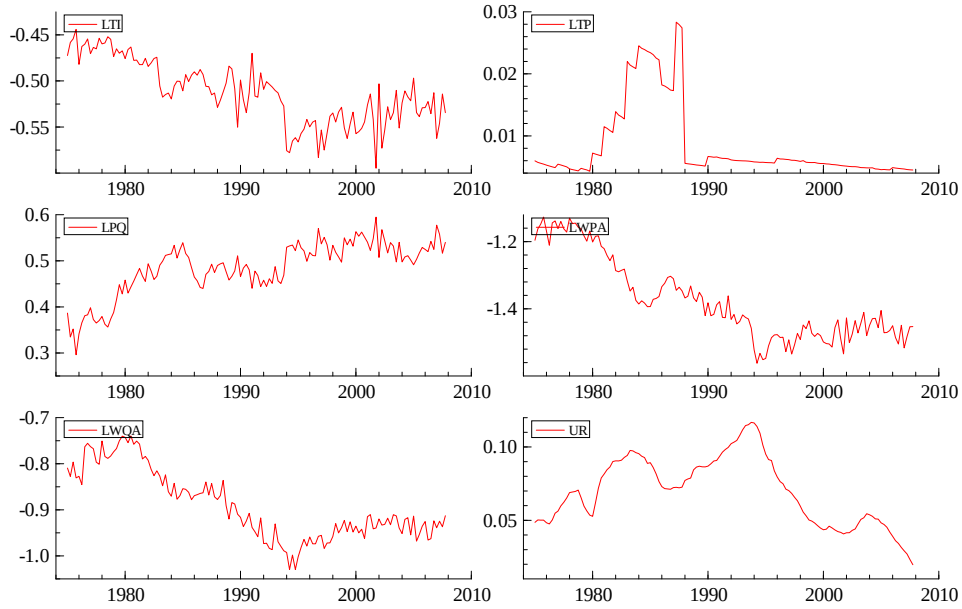

Chart 3b: Data

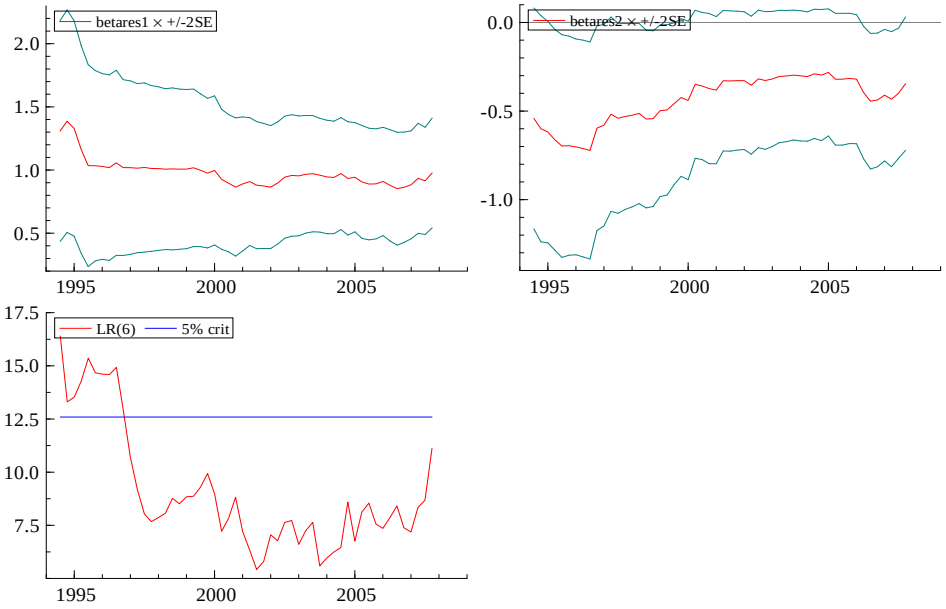

Chart 4: Recursive cointegration results

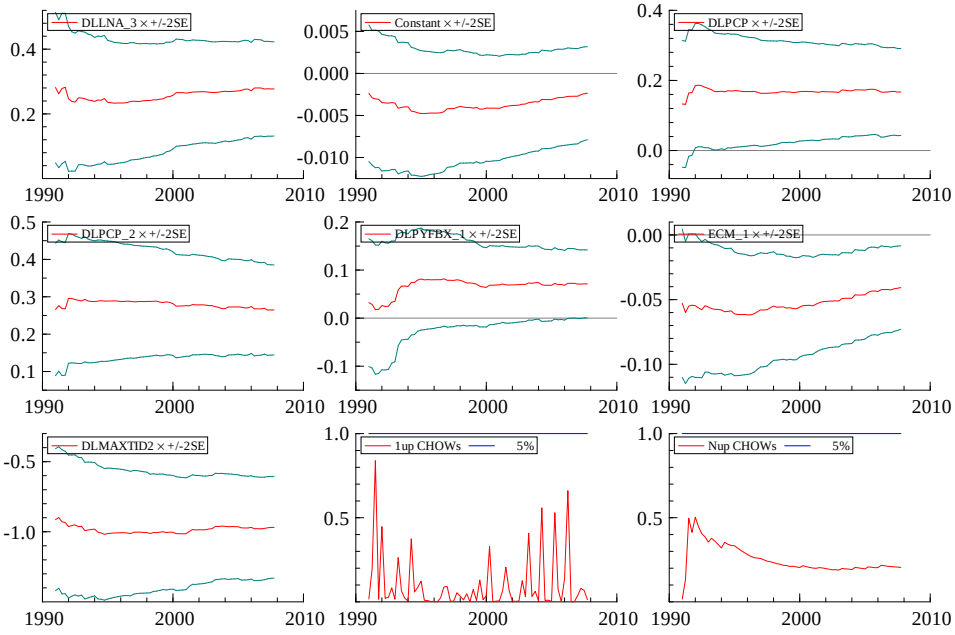

Chart 5: Recursive estimation of dynamic wage equation

		Level			First difference	
Variable	Det.	Augm.	ADF	Det.	Augm.	ADF
w	C,T	2	-4.04**	C	3	-3.47*
p	C,T	0	-8.79**	C	1	-6.55**
q	C,T	1	-2.13	C	3	-3.71**
w_p	C,T	2	-1.77	C	1	-11.4**
w_q	C,T	1	-2.23	C	0	-15.9**
U	C	1	-1.08	C	0	-4.38**
t_p	C	3	-1.57	C	2	-9.10**
t_i	C	2	-1.93	C	1	-13.74**
a	C,T	1	-2.49	C	1	-10.96**
h	C,T	3	-1.46	C	2	-4.33**
r	C	1	-1.22	C	0	-16.72**
p_q	C,T	1	-3.50*	C	0	-16.66**
$w_p - a$	C	2	-1.86	C	1	-12.51**
$w_q - a$	C	2	-1.14	C	1	-11.82**

Table 1: ADF tests

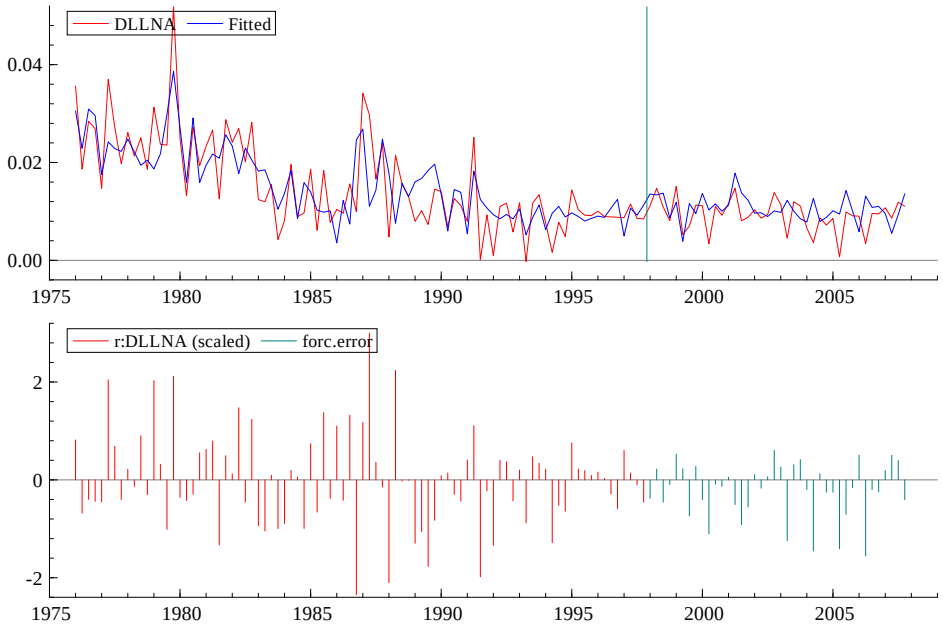

Chart 6: Out-of-sample forecasts

Equation	AR 1-5	ARCH 1-4	Hetero.	Normality
Test statistic distribution	F(5,91)	F(4,88)	F(44,51)	χ^2 (2)
w	1.37	1.18	0.82	3.27
a	1.72	0.30	0.68	0.09
p	0.99	2.74*	1.03	2.48
U	0.80	0.40	0.75	12.92**
p_q	1.12	0.26	0.72	0.65
Test statistic distribution	F(125,334)	..	F(660,594)	χ^2 (10)
System	1.05	..	0.75	18.52*

Table 2: Diagnostic tests

Rank	Trace	Max	Trace (T-nm)	Max (T-nm)
0	103.96 **	41.42**	87.72**	34.94*
1	62.55 **	35.80**	52.77*	30.21*
2	26.75	21.16*	22.57	17.86
3	5.59	3.71	4.71	3.13
4	1.87	1.87	1.58	1.58

Table 3: Cointegration tests

Test	Distribution	Statistic
AR 1-5	F(5,116)	2.20
ARCH 1-4	F(4,113)	2.45
Normality	χ^2(2)	7.82*
Hetero	F(12,108)	1.52
Hetero-X	F(27,93)	1.49
RESET	F(1,120)	12.3**

Table 4: Specification tests