The Cause of Unemployment: Demand or Supply Shocks?

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Abstract: We study the Danish unemployment experience 1905-92 using a common trends model with cointegration constraints. To justify the identifying assumptions about the cointegration vectors and the common trends we present a simple macroeconomic model of the labor market. The model determines the long run behavior of labor productivity, employment, unemployment, real product and real consumer wages. The empirical results give support for three cointegration relations and two common trends. Based on the economic model the trends are interpreted as representing labor productivity (technology) and labor supply. With unemployment being nonstationary, the common trends analysis indicates that labor supply shocks is the primary source for explaining the behavior of unemployment.

Keywords: Cointegration, common trends, supply and demand shocks, unemployment.

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1. Introduction

A fundamental problem in economics is to explain the behavior of unemployment. One of the first and most influential empirical results was the negative correlation between wage inflation and unemployment recorded by Phillips and others. At the time, many economists interpreted this as depicting a tradeoff between inflation and unemployment.

The experiences of most Western European countries since the 1970's has lead many economists to question not only the existence of a tradeoff (which can be utilized by policy makers), but also the ("Keynesian") view that unemployment is a purely cyclical phenomenon. As a response, there has been a change of focus in the literature from the Phillips curve towards a relation between the level of the real wage and unemployment, and towards the determinants of the natural (equilibrium) rate of unemployment.

One of the most influential empirical papers in recent years is the comparative study of 18 OECD countries by Bean, Layard, and Nickell (1986). By analysing error correction models for real wages and employment they find that changes in labor demand and supply are about equally important in explaining excess supply of labor. Moreover, labor markets seem to adjust faster to different types of shocks in countries that are more corporatist in nature (such as the Nordic countries), and these countries often show strong long run effects of unemployment on wages.[1]

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[1] A large number of papers followed the study by Bean et al. (1986); for recent surveys, see e.g. Bean (1994) and Elmeskov (1994).

The single (and two) equation(s) error correction approach to analysing the labor market has been challenged in two recent papers by Jacobson, Vredin, and Warne (1998, 1997). They point out that some of the variables which are taken as exogenous by Bean et al. (1986) should be treated as endogenous. Once labor productivity and the labor force are modelled jointly with employment and real wages, Jacobson et al. find evidence (on Scandinavian data) suggesting that the high perceived elasticity of real wages with respect to unemployment reflects that unemployment reacts faster and much less to transitory labor demand shocks than real wages, and that there is no strong evidence of a long run relation (in terms of a common permanent shock) between these two variables.

In this paper we follow the proposal made by Jacobson et al. (1998, 1997) by analysing a small macroeconomic model of the labor market in which all variables of interest are treated as endogenous. We extend the model discussed in Jacobson et al. (1997) by including a relation for the ratio of consumer to producer prices. This allows us to take into account that consumers and producers are concerned with different real wage measures.

In the empirical analysis we use long time series of annual data (1905-1992) from Denmark. We focus our attention on the responses in unemployment, real wages (for consumers and producers), and the real unit labor cost (the wage share) to changes in certain shocks. Our interest in the wage share is governed by the frequent empirical finding of cointegration between unemployment and the wage share.[2]

The paper is organized as follows: In Section 2 we present a simple macroeconomic model of the labor market. The model can be consistent with the views of Bean et al. (1986) as well as with more elaborate standard models of the labor market; see Lindbeck (1993), Bean (1994), and Wyplosz (1994). In Section 3 we present the data and the results from a cointegration analysis of the reduced form of the empirical model. The long run properties of the estimated structural form are given in Section 4, while the dynamics are investigated in Section 5. Finally, the main findings are summarized in Section 6.

2. A Macroeconomic Model of the Labor Market

In this section we present a simple, log-linear, macroeconomic model of the labor market. Our main objective is to analyse the long run behavior of unemployment and, hence, we restrict the description of the short run dynamics to a minimum.

Jacobson et al. (1997) presents a standard macro oriented labor market model with four basic relations: a labor supply, a labor demand, a wage setting relation and a production function. These relations are influenced by propagation mechanisms through which e.g. technology shocks can affect the endogenous variables. We extend their model by including a relation which determines the behavior of the wedge between consumer and producer prices. This enables us to (i) differentiate between the real wages relevant to producers and to consumers, respectively, and (ii) study the importance of aggregate demand (or relative price) shocks on the labor market.

[2] See e.g. Drèze and Bean (1990) where the wage relations for 5 out of 10 countries are error correction models in which the wage share and unemployment enters in the error correction term.

Table 1 presents the model for the five endogenous variables (the labor force, labor productivity, employment, the real wage, and the price wedge) and the dynamics of the exogenous variables. We represent the deterministic components ($f_i(t)$, $i = l, y, e, w, p$) as general functions of time, thereby allowing us to concentrate on the stochastic formulation of the model.

Equation (1) gives the labor force, l_t, as a function of the real consumer wage, $w_t - q_t$, where α measures the supply elasticity. In addition, there is an exogenous labor supply term, $\theta_{l,t}$, representing institutional factors (eg. working hours regulations, retirement laws, etc.) and/or demographic factors (eg. changes in population size and distribution). We assume that institutional and demographic changes have highly persistent effects on the labor force, as reflected by $\theta_{l,t}$ being a random walk with innovation $\varepsilon_{l,t}$, a pure labor supply shock.

The level of output is determined by a Cobb-Douglas function. In (2) this production function is formulated as a relation describing average labor productivity. The parameter $\beta > 0$ is the returns to scale parameter in the production function. The evolution of average labor productivity over time is given by a deterministic growth process, $f_y(t)$, and a stochastic technology process, $\theta_{y,t}$. Both processes can be composite functions in which the (log of the) capital-labor ratio enters along side a pure technology process. The stochastic part is modelled as a random walk (equation (7)) with $\varepsilon_{y,t}$ being a productivity innovation.[3]

Equation (3) specifies the desired employment as a function of the level of output, y_t, and the real product wage, $w_t - p_t$. We assume that firms demand labor according to a partial adjustment rule and equation (8) specifies this rule by the restriction on the parameter ρ_e. The parameter β is the returns to scale parameter as in (2).

The consumer real wage is, for instance, determined by a bargaining process between firms and labor unions. Here, the outcome of this process is described as a relation between the consumer real wage, average labor productivity and unemployment in equation (4).[4] The variable $\theta_{w,t}$ measures the influence of wage shocks, $\varepsilon_{w,t}$, on wage setting. Also, the parameter ρ_w can be interpreted as reflecting the stability of the bargaining process; ρ_w close to zero corresponds to small dynamic effects of temporary wage shocks, while $\rho_w = 1$ represents a situation where such shocks have a permanent effect on wage setting behavior.

In equation (5) we have a reduced form equilibrium relation for the wedge between consumer and procucer prices and the mark-up of prices over unit labor costs. Here, the wedge is primarily seen as a measure of (international) competitiveness.[5] As our main interest is the behavior of

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[3] The derivation of the equation is discussed in more detail in Appendix A.

[4] Unemployment is specified as $l_t - e_t = -\ln(1 - u_t) \approx u_t$ where u_t is the unemployment rate.

[5] Assuming the consumer price is given as

$$q_t = \lambda p_t^* + (1 - \lambda)p_t,$$

it follows that

$$q_t - p_t = \lambda(p_t^* - p_t),$$

where p_t^* is the world price of output in domestic currency. The term $p_t^* - p_t$ is often labeled as the level of international competitiveness, see e.g. Layard, Nickell, and Jackman (1991) and in (5) we implicitly model the relation

$$p_t^* - p_t = -\lambda^{-1}\delta(p_t - (w_t + e_t - y_t)) + \lambda^{-1}\theta_{g,t}.$$

unemployment, we choose to call this relation a goods market relation. The variable $\theta_{g,t}$ therefore captures the influence of goods market shocks (aggregate demand and/or price shocks) on the labor market. Since such shocks have been stressed in the literature as a possible source for unemployment hysteresis, we allow for the possibility that ρ_g is equal to unity.[6]

To close the model we assume that the initial values of the exogenous variables are all equal to zero, and that the five pure innovations are independent over time, mutually independent with mean zero and constant variances.

The model has a unique solution provided that the parameter, $\psi = \gamma_2 + (\beta - 1)(\gamma_1 - (1 + \alpha\gamma_2)\delta)$, is nonzero. Here, we only present and discuss the specific parameters on the labor productivity and supply trends.[7] In terms of the variables we study in the following sections, the solution is:

$$\begin{aligned}
\begin{bmatrix} y_t - e_t \\ e_t \\ l_t - e_t \\ w_t - p_t \\ w_t - q_t \end{bmatrix} &= \psi^{-1} \begin{bmatrix} \psi + (\beta - 1)(1 - \gamma_1 + (1 + \alpha)\gamma_2) \\ 1 - \beta\gamma_1 + \alpha\gamma_2 + (\beta - 1)(1 + \alpha\gamma_2)\delta \\ \beta\gamma_1 - 1 - (\beta - 1)(\delta - (\alpha\gamma_1)(1 - \delta)) \\ \psi \\ \psi + (\beta - 1)(1 - \gamma_1 + (1 + \alpha)\gamma_2)\delta \end{bmatrix} \beta^{-1}\left[\theta_{y,t} + f_y(t)\right] \\
&+ \psi^{-1} \begin{bmatrix} (\beta - 1)\gamma_2 \\ \gamma_2 \\ (\beta - 1)(\gamma_1 - \delta) \\ 0 \\ (\beta - 1)\gamma_2\delta \end{bmatrix} \left[\theta_{l,t} + f_l(t)\right] \\
&+ B_e\left[\theta_{e,t} + f_e(t)\right] + B_w\left[\theta_{w,t} + f_w(t)\right] + B_g\left[\theta_{g,t} + f_g(t)\right].
\end{aligned} \tag{13}$$

By the assumption of a stationary labor demand schedule and right-to-manage type wage setting it follows that the producer real wage equals the marginal productivity of labor. Thus, in the long run the producer real wage is independent of all exogenous shocks apart from productivity shocks where the response is soley determined by the size of β. The long run responses in the other endogenous variables to changes in the exogenous are ambigous in (13). Therefore, we will briefly discuss four special cases with emphasis on the long run responses in unemployment and the real unit labor cost measured as $w - p - (y - e)$.[8] For simplicity, we assume $\rho_w, \rho_g < 1$, whereby only labor supply and productivity shocks matter in the long run. Moreover, we let $\alpha = 0$ implying an

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If $\gamma_1 = 1$ in the wage setting relation (4), the goods marked relation can be written as

$$q_t - p_t = -\frac{\delta}{1 - \delta}\gamma_2(l_t - e_t) + \theta_{g,t}.$$

This trade off between competitiveness and unemployment is common in most open economy models.

[6] One interpretation of the stochastic processes for wage and goods market shocks is that they represent partial adjustment rules which may arise from staggered price setting behavior or from adjustment costs.

[7] The complete solution is given in appendix B.

[8] We refer to this variable as the wage share.

exogeous labor supply. The parameter constellations and long run responses in the endogenous variables are listed in Table 2.

First, when $\beta = 1$ (constant returns to scale; cf. Case 1), neither unemployment nor any of the real wage measures, including the wage share, respond to labor supply shocks. The wage share is also unaffected by labor productivity shocks while the response in unemployment is determined by γ_1. If $\gamma_1 > 1$, unemployment will increase from a positive productivity shock (as in Aghion and Howitt, 1994), while the reverse result follows when $\gamma_1 < 1$ (as in Pissarides, 1990). If $\gamma_1 = 1$, there is no long run effect on unemployment implying stationarity of both unemployment and the wage share while the two real wages are non-stationary.

In the second case we let $\delta = \gamma_1 = 1$ whereby the wage setting and the goods market relations generate a stationary relation between the consumer real wage and average labor productivity. In this case unemployment is independent of both labor supply and productivity shocks while the wage share responds to both shocks unless the production function has constant retuns to scale. If $\beta < 1 (> 1)$ the wage share increase (decrease) following positive shocks to either labor productivity or supply.

Third, we let $\delta = 0$, $\gamma_2 = 0$ and $\gamma_1 = \beta^{-1} \neq 1$. With this setting unemployment responds one-to-one to labor supply shocks while there is no response to productivity shocks. In contrast, the wage share reponds to productivity shocks but not to labor supply shocks.[9]

In the last two cases employment is independent of productivity shocks. We think of these cases as being similiar (in spirit) to the hysteresis model of Blanchard and Summers (1986).[10] We wish to emphasize that the independece of employment and productivity shocks is neither necessary nor sufficient for non-stationarity of unemployment (eg. hysteresis effects) once we allow for a non-stationary labor supply.

For the last example we consider the case when $\delta = 0$ (stationary price wedge), $\gamma_2 > \gamma_1(1 - \beta)$ (labor supply shocks have a positive effect on employment), and $\gamma_1 > \beta^{-1}$ (wage earners are over-compensated for labor productivity increases). We again find that productivity shocks have positive effects on labor productivity and the two real wage measures. Since the labor force is exogenous ($\alpha = 0$), the effect from productivity shocks on unemployment is a mirror image of the effect employment. In this case, the assumption that wage earners are over-compensated for labor productivity increases means that employment falls and, hence, that unemployment increases.

By assumption, labor supply shocks are positively related to employment. The effect of such shocks on unemployment and labor productivity depends entirely on the returns to scale parameter. With β being less (greater) than unity, unemployment and labor productivity both fall (rise).

The main results from these examples are: (i) constant returns to scale is neither necessary nor sufficient for stationarity of unemployment, (ii) the comovement between any of the real wage measures and unemployment can be positive as well as negative, and (iii) unemployment may be

[9] If $\gamma_2 \neq 0$ the responses to labor supply shocks in average productivity, employment and unemployment become indeterminate. With decreasing returns to scale the response in unemployment will be negative while the response in the wage share will be positive.

[10] An insider union may well have the objective $\partial e / \partial \theta_y = 0$ and this is what is described in Blanchard and Summers (1986).

non-stationary and the underlying stochastic trend may be either labor productivity or supply (or both). Furthermore, the response in unemployment to either shock can be positive as well as negative.

In the remainder of the paper we shall analyse data for the Danish labor market spanning most of the current century. The analysis is based on a vector autoregressive model for empirical measures of the five variables in (13). The VAR model allows for richer short run dynamics, and yet its long run behavior can be consistent with that of the theoretical model. In particular, the theoretical parameters may be identified from the so called cointegration and common trends spaces of the VAR, while the theoretical shocks may be identified via the VAR innovations.

3. Empirical results for the reduced form

The data set consists of annual observations covering the period 1901 to 1992.[11] The output measure (y) is real GDP at factor prices for the nonagricultural sector. Employment (e) is likewise for the nonagricultural sector (measured in hours), while unemployment ($l-e$) is given as $-\ln(1-u)$ where u is the ratio of the total number of unemployed to the total number of individuals in the labor force. The nominal wage series (w) is an index of the hourly wage for the manufacturing industries, while the price series are the implicit GDP deflator (p) and the deflator for private consumption (q).

In addition to the five endogenous variables a number of 0/1 dummy variables have been included; see Table 3. Most of the dummies are fairly uncontroversial, such as the two world war dummies (WWI,WWII) and the two oil price dummies (OILI,OILII). The two dummies, D1919 and D1945, have been included to allow for end of war effects and because some of the data have been constructed by interpolation during the war periods without restrictions on the end effects. The last dummy, denoted by STATE in Table 3, has been introduced as an attempt to capture the expansion of the public sector during the 60's and the 70's. During this period the share of public sector employment to total employment (corrected for differences in part time employment) rose from about 10 percent to almost 30 percent. The bulk of this increase occured during the late 60's and the 70's when the growth rate of public sector employment was roughly twice as high as the growth rate of total employment. Ideally, we would prefer to model the private nonagricultural sector. However, we cannot decompose the variables into the public and the private sector, respectively, during 1901 to 1947. We have therefore chosen to model the rapid expansion of the public sector as a 0/1 dummy.

In the empirical analysis we use a VAR model with four lags for the vector $x_t' = [(y_t - e_t) \;\; e_t \;\; (l_t - e_t) \;\; (w_t - p_t) \;\; (q_t - p_t)]$.[12] The number of common trends and cointegration vectors have been estimated using the maximum likelihood approach suggested by Johansen (1988, 1991). Table 4 reports likelihood ratio statistics, 95 percent (asymptotic) critical values, and p-values for the tests

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[11] All series are given in natural logarithms. The data are taken from Kærgård (1991) and the data bank for the Danish macro model ADAM. The two sets have been linked in 1970–71 and the links are described in Kærgård (1991) and Hansen (1994).

[12] The lag order of the VAR was determined from a sequence of likelihood ratio tests; see Hansen and Warne (1995) for these results and additional specification analysis.

of the number of common trends. Using a 5 percent level of marginal significance we find evidence of 2 common trends, although the support for the second trend is not overwhelming.

Identification of the structural model rests on the assumptions of unit roots in the labor productivity and the labor supply relations. In the top two rows of Table 5 we report likelihood ratio tests for the hypotheses of stationarity of these two processes. While both hypotheses are rejected at the 5 percent level, the p-value for the former hypothesis is quite high (4 percent). Still, these results suggest that the labor productivity relation and the labor supply curve are indeed influenced by unit root processes.

Tests of various model consistent restrictions on the steady state parameters are also reported in Table 5. For instance, the hypothesis that the wage share, unemployment, and the price wedge are all stationary implies that $\beta = \gamma_1 = 1$ in the theoretical model. The joint hypothesis is strongly rejected by the data. However, the hypothesis of a stationary price wedge ($\beta = 1$ or $\delta = 0$ in the theoretical model) is a borderline case with a p-value of 4 percent.

To summarize, the main findings of the reduced form cointegration analysis are: (i) there is evidence of two common trends (three stationary relations); (ii) the common trends may be identified according to the theoretical model; and (iii) the wage share and unemployment both seem to be nonstationary.

4. Empirical results for the structural model

In this section we present maximum likelihood estimates of the structural parameters and of the long run solution. The parameter α in equation (1) is estimated in the common trends form of the model (see Warne, 1993), while the remaining parameters are estimated in the error correction form (see Johansen and Juselius, 1994).

Table 6 reports the estimated long run relations. In view of the economic model, the point estimates seem reasonable, and the overidentifying restrictions on the cointegration relations are not rejected.[13] Both $\hat{\beta}^{-1}$ and $\hat{\gamma}_1$ are significantly greater than unity while α is significantly greater than zero. This means that we expect unemployment to be influenced by both trend shocks in the long run.

The responsiveness of wages to unemplyment has been a focal point in the debate about the European unemployment problem. Although there is some ambiguity in the precise measure, two of the measurements often used are the partial (long run) elasticities of the consumer and producer real wages with respect to unemployment, respectively. Our estimates ($\hat{\gamma}_2 = .085$, $\hat{\gamma}_2/(1-\hat{\delta}) = .129$) corresponds reasonably well to those reported in Drèze and Bean (1990), Table 1.3, although our estimates are sligthly higher than the ones given in their Table. This, on the other hand, is in accordance with the findings in Bean et al. (1986) and Calmfors and Driffill (1988). These studies report a positive relation between the responsiveness of wages to unemployment and the level of corporatism (where Denmark is given a high ranking).

[13] With 3 cointegration relations and 5 endogenous variables, the number of free parameters is 6. The stationary relations in the labor market model has 4 free parameters ($\beta, \gamma_1, \gamma_2, \delta$), thus implying 2 restrictions on the cointegration space.

Table 7 reports the estimated coefficients in the long run solution for the five variables given in (13) and the wage share. The estimates are based on the normalized trends (ie. both trend shocks have unit variance). Thereby, the coefficients measure the long run effect (reported in percent) on the endogenous variables from unit (one standard deviation) shocks to the trend innovations.

In the first column we find the long run elasticities with respect to the productivity trend. The responses in average labor productivity and the two real wage measures are almost equal and quite close to a one-to-one response. However, as expected when $\hat{\beta} < 1$, there is a significant positive response in the wage share. The point estimates of the responses in employment and unemployment are both positive with large standard errors.

The results for the productivity shocks provides some support for the view about wage setting as it is expressed in Blanchard and Summers (1986). The rise in unemployment in our model is due to the endogeneity of the labor force; it increases in response to the higher level of the consumer real wage. As already mentioned, however, the long run responses in employment and unemployment with respect to productivity shocks are not estimated with good precision.

The second column in Table 7 presents the long run responses to labor supply shocks. Such shocks raise employment and the wage share while unemployment and the consumer real wage fall. The main reason for these results is the decreasing returns to scale in production, but the value of γ_2 (the responsiveness in wages with respect to unemployment) relative to the returns to scale parameter is also important. The order of magnitude is interesting: the response in employment is one-to-one while unemployment drops by half a percentage point. In contrast, the responses in the real wage measures are quite small.

The results with respect to labor supply shocks are in line with the findings in Jacobson et al. (1997). Specifically, for Denmark (quarterly data, 1970-90) they record a negative response in unemployment following a positive labor supply shock.

We have investigated the robustness of our evidence in several ways and, here, we will briefly discuss some of our analyses: First of all, we tested the basic model for parameter constancy using the tests proposed by Nyblom (1989) and Hansen (1992), and at the five percent level the hypothesis of parameter constancy cannot be rejected.

Second, the VAR model was estimated under the assumption of one common trend and the joint hypothesis of stationarity of the wage share, unemployment, and the price wedge was tested. The hypothesis was rejected at the 1 percent level. Thus, the rejection of the hypothesis $\beta = 1$ and $\gamma_1 = 1$ is not a result of the choice of two common trends rather than just one.

Third, we analysed the implications of our assumption of estimating the returns to scale from the labor demand equation. This was done by respecifying equation (2) to

$$y_t - e_t = f_y(t) + (\tilde{\beta} - 1)e_t + \theta_{y,t},$$

where $\tilde{\beta}$ was chosen freely.

For the respecified model the point estimates of α and σ_l are negatively related, while σ_y is positively related to $\tilde{\beta}$. Values of $\tilde{\beta}$ in the interval [0.8,1.2] yield only minor changes in the point estimates of the three parameters. Moreover, the analysis shows that if we impose the restriction of an exogenous labor force in the long run ($\alpha = 0$), as in Jacobson et al. (1998), the estimated returns to scale parameter is in excess of 1.4. We conclude that our chosen identifying assumption is prefered over the alternative of $\alpha = 0$.

Finally, since the stationarity of the price wedge is a border line case, the model was estimated under the restriction of a stationary price wedge ($\delta = 0$). The estimates for this model, in terms of the long run solution, are shown in the last two columns of Table 7. Comparing the evidence from the two models, $\delta \neq 0$ and $\delta = 0$, we find the results to be largely unaltered or to some extent sharper for the latter model: employment is still not responding to productivity shocks while the point estimate of the increase in unemployment has risen (albeit it is still not significant) and the response in the wage share is larger. The responses to labor supply shocks are largely similar for employment and unemployment while the response in the wage share has roughly doubled in the latter model.

5. The dynamics in the structural model

In this section we present the impulse response functions for the two common trend shocks, and we discuss the relative importance of the permanent and transitory shocks using variance decompositions.

Figure 6 shows the dynamic responses from a unit shock in period 0 in productivity and labor supply, respectively. The propagation mechanisms are dominated by business cycle fluctuations with a frequency of 5-7 years. Average labor productivity and both real wage measures increase instantaneously from a productivity shock and the long run levels seem to be reached after a period of 10 years. In contrast, we do not find any significant responses in either employment or unemployment at any horizons. For the wage share we do not record any significant responses for the first 20 years after which it has reached the long run level.

We do not record any significant responses in the producer real wage following a labor supply shock.[14] The consumer real wage and the wage share both respond instantanously with significant downswings while the responses in the subsequent periods are insignificant. However, from Section 4 we know that the response in the consumer real wage will ultimately be negative while the long run response in the wage share is positive. Employment and unemployment also react instantanously. Unemployment by dropping roughly 1 percentage point while the long run response of approximately 0.5 percent is reached after 10 years.

The reponses to the two shocks, long run as well as dynamic, offer a possible explanation of the frequent finding of a cointegration relation between unemployment and the wage share (see e.g. Drèze and Bean, 1990, Table 1.4): A linear combination of the wage share and unemployment will remove the labor supply trend, while effects from productivity shocks are probably very difficult to detect in shorter samples than our. Therefore, the only apparent nonstationarity in unemployment and the wage share is the labor supply trend, and this trend is removed by the linear combination $(w + e - p - y) - (\gamma_2/(\gamma_1 - \delta))(l - e)$. With γ_1 being close to unity this parameter is very close to the responsiveness of the producer real wage to unemployment ($\gamma_2/(\gamma_1 - \delta) = .116$).

[14] We have not imposed zero responses at finite horizons.

The relative importance of the different shocks are presented in Table 8. Here, the forecast error variances are decomposed into three components; innovations in the productivity trend, the labor supply trend, and the joint influence of the transitory innovations; we do not attempt to identify the individual transitory shocks.)

Table 8 shows pronounced differences between the endogenous variables. It seems as if it is possible to make a complete classification of the endogenous variables according to the dominating source of forecast uncertainty. The two measures of the real wage are dominated by shocks to the productivity trend even at the very short horizons, while labor supply shocks have only small effects at all horizons. For employment and unemployment labor supply shocks is the main source of uncertainty at all horizons. Moreover, while employment is influenced by transitory shocks in the short run, unemployment is not. Although the fraction of the forecast error variance for unemployment is not 100 percent we are not able to tell if the remaining part is due to productivity shocks or to transitory shocks. Finally, for average labor productivity and the wage share more than half of the variation within the first two years can be attributed to transitory shocks, while labor supply shocks have a negligible influence at all finite horizons we record. In addition, for the wage share the effects of transitory shocks seem to be considerable even at the 12 years horizon. One explanation for this finding is that the wage share is not far from being stationary, and the dominating nonstationary component, the labor supply trend, has a small variance.

6. Conclusions

In this paper we analyse the Danish unemployment experience during 1905-92 using a structural VAR model with cointegration constraints. Our primary concerns are if there are shocks with permanent effects on unemployment, and what the sources of these shocks may be.

To study these questions we follow the suggestion made by Jacobson et al. (1997) and formulate a simple macroeconomic model of the long run behavior of the labor market. The model is conventional in the sense that it contains a labor demand, a labor supply, and a wage setting relation. In contrast to Jacobson et al. (1997), we do not fix the returns to scale parameter in the production function, and we include a relation for the goods market where the price wedge is a function of the mark-up of prices over unit labor costs. These five relations are influenced by exogenous variables, representing supply and demand shocks and their propagation mechanisms.

Among the exogenous variables at least two are assumed to be stochastic trends; a productivity and a labor supply trend. A third trend may arise from shocks to the wage setting relation, while a fourth trend may be due to price (or aggregate demand) shocks. In that sense, the model is consistent with both supply and demand shocks having permanent effects on unemployment. Furthermore, under certain parametric conditions unemployment is stationary.

We find support for the hypothesis of two common trends in the Danish data. Moreover, at the 5 percent level, we reject the hypotheses that a linear combination between labor productivity and employment and a linear combination between the labor force and the real consumer wage are stationary, thereby supporting the assumptions about unit roots in productivity and labor supply. The stationary relations suggested by the model puts restrictions on the cointegration space and these cannot be rejected by the data. Once these restrictions are imposed, the estimated structural parameters are consistent (in terms of signs and magnitudes) with the theoretical interpretations of the long run relations. However, the restrictions implied by unemployment being stationary are rejected.

The analysis of the structural VAR model indicate that positive labor supply shocks lead to lower unemployment while the wage share rises in the long run. An interpretation of the negative relation between labor supply shocks and unemployment is the following: when the labor demand elasticity with respect to output is (slightly) greater than unity, a shift in the long run labor demand curve due to labor supply shocks (via output) will be positive and greater than the shift in the supply curve as long as the supply elasticity is sufficiently small. Given the wage setting relation, the consequence is that employment increases by a larger fraction than the labor force, thereby decreasing the unemployment rate.

Productivity shocks, on the other hand, tend to have positive effects on real wages and unemployment. With the effect on employment being (close to) zero, the reaction in unemployment is (mainly) determined from the labor supply relation; if the elasticity on wages is positive (negative), unemployment will rise (fall), and we record a positive supply elasticity.

Overall, we find labor supply shocks to be the main determinant of the rate of unemployment. It is not possible, however, to fully explain the nature of these shocks from the simple economic model. One conjecture is that they reflect institutional and demographic changes in the labor market. For instance, the work week has changed from 6 days to 5 within the sample, working hours have decreased substantially, and unemployment benefits have been introduced. Such factors are probably important when analysing the supply of labor and may account for the negative correlation between unemployment and the labor supply trend. Nevertheless, in view of the existing theory about unemployment, our results are not unreasonable and may, at least, be taken as a point of departure for further analysis about the sources of unemployment.

Appendix A. The production technology

In this appendix we discuss the derivation of the productivity trend. The main purpose is to show the effect of the omission of capital and/or user-cost for capital from the model.

We consider a Cobb-Douglas production function with two inputs: labor and capital. For simplicity we discard constants and trends. The production function is written in log-linear form with labor augmenting technological progress, described by a scale parameter a_t.

$$y_t = \beta_1(a_t + e_t) + \beta_2 k_t, \quad \beta_1 + \beta_2 = \beta, \tag{14}$$

where e_t is employment and k_t is capital.

The production function is rewritten to a relation for average labor productivity where β is the returns to scale parameter

$$y_t - e_t = (\beta - 1)e_t + \beta_2(k_t - e_t - a_t) + \beta a_t. \tag{15}$$

Here $(k_t - e_t - a_t)$ is the capital/labor ratio with labor measured in effective units.

The pure technological process is assumed to be a random walk.

$$a_t = a_{t-1} + \varepsilon_{a,t}.$$

To model (the natural logarithm of) technology as an autoregressive process is common in, for instance, the real business cycle literature; see also King, Plosser, Stock, and Watson (1987) where technology is a random walk within a Solow type growth model. The assumption that the process is a random walk rather than a stationary but highly persistent process is somewhat arbitrary, but it may be justified on the grounds that technological progress is an important factor for explaining growth in real output.

Using an assumption of cost-minimization and price taking firms we derive two demand relations. These are assumed to be stationary

$$e_t = \beta^{-1} y_t - (w_t - p_t) + \theta_{e,t}, \tag{16}$$

$$k_t = \beta^{-1} y_t - (r_t - p_t) + \theta_{k,t}. \tag{17}$$

w_t is the wage rate and r_t is the user-cost of capital.[15]

Combining the two demand relations and subtracting a_t we obtain (as usual)

$$k_t - e_t - a_t = w_t - a_t - r_t + \theta_{k,t} - \theta_{e,t}. \tag{18}$$

Since we do not model r_t we need to consider two cases; $w_t - a_t - r_t$ may be either stationary or non-stationary (I(1)). From (15) and (18) it follows that $\theta_{y,t}$ in (2) is given by

$$\theta_{y,t} = \begin{cases} \beta a_t + \beta_2(k_t - e_t - a_t) & \text{for } w_t - a_t - r_t \sim \mathrm{I}(1), \\ \beta a_t & \text{for } w_t - a_t - r_t \sim \mathrm{I}(0). \end{cases} \tag{19}$$

By defining $\theta_{y,t}$ as a productivity process both cases are valid descriptions. Furthermore, as long as our interest is centered on average productivity and employment our inference (leaving out k_t and r_t) is valid.

[15] The two processes $\theta_{e,t}$ and $\theta_{k,t}$ are in general highly correlated. In the extreme case in which labor demand is perfectly flexible the error processes may be perfectly correlated.

Appendix B. The solution of the model

The complete solution of the model, where $\psi = \gamma_2 + (\beta - 1)(\gamma_1 - (1 + \alpha\gamma_2)\delta)$, is given by

$$\begin{bmatrix} y_t - e_t \\ e_t \\ l_t - e_t \\ w_t - p_t \\ w_t - q_t \end{bmatrix} = \psi^{-1} \begin{bmatrix} \psi + (\beta - 1)(1 - \gamma_1 + (1 + \alpha)\gamma_2) \\ 1 - \beta\gamma_1 + \alpha\gamma_2 + (\beta - 1)(1 + \alpha\gamma_2)\delta \\ \beta\gamma_1 - 1 - (\beta - 1)(\delta - (\alpha\gamma_1)(1 - \delta)) \\ \psi \\ \psi + (\beta - 1)(1 - \gamma_1 + (1 + \alpha)\gamma_2)\delta \end{bmatrix} \beta^{-1}\left[\theta_{y,t} + f_y(t)\right]$$

$$+ \psi^{-1} \begin{bmatrix} (\beta - 1)\gamma_2 \\ \gamma_2 \\ (\beta - 1)(\gamma_1 - \delta) \\ 0 \\ (\beta - 1)\gamma_2\delta \end{bmatrix} \left[\theta_{l,t} + f_l(t)\right] + \psi^{-1} \begin{bmatrix} (\beta - 1)(1 + \alpha\gamma_2)(1 - \delta) \\ (1 + \alpha\gamma_2)(1 - \delta) \\ -(1 - (\beta - 1)\alpha\gamma_1)(1 - \delta) \\ \psi \\ (\gamma_2 + (\beta - 1)\gamma_1)(1 - \delta) \end{bmatrix} \left[\theta_{e,t} + f_e(t)\right]$$

$$+ \psi^{-1} \begin{bmatrix} -(\beta - 1) \\ -1 \\ 1 - (\beta - 1)\alpha\delta \\ 0 \\ -(\beta - 1)\delta \end{bmatrix} \left[\theta_{w,t} + f_w(t)\right] + \psi^{-1} \begin{bmatrix} -(\beta - 1)(1 + \alpha\gamma_2) \\ -(1 + \alpha\gamma_2) \\ 1 - (\beta - 1)\alpha\gamma_1 \\ 0 \\ -\gamma_2 - (\beta - 1)\gamma_1 \end{bmatrix} \left[\theta_{g,t} + f_g(t)\right].$$

TABLE 1: The theoretical model.

$$
\begin{aligned}
l_t &= f_l(t) + \alpha(w_t - q_t) + \theta_{l,t}, && (1)\\
y_t - e_t &= f_y(t) + (\beta - 1)e_t + \theta_{y,t}, && (2)\\
e_t &= f_e(t) + \beta^{-1} y_t - (w_t - p_t) + \theta_{e,t}, && (3)\\
w_t - q_t &= f_w(t) + \gamma_1(y_t - e_t) - \gamma_2(l_t - e_t) + \theta_{w,t}, && (4)\\
q_t - p_t &= f_p(t) - \delta(p_t - (w_t + e_t - y_t)) + \theta_{g,t}, && (5)
\end{aligned}
$$

$$
\begin{aligned}
(1 - L)\theta_{l,t} &= \varepsilon_{l,t}, && (6)\\
(1 - L)\theta_{y,t} &= \varepsilon_{y,t}, && (7)\\
(1 - \rho_e L)\theta_{e,t} &= \varepsilon_{e,t}, \quad 0 \le \rho_e < 1, && (8)\\
(1 - \rho_w L)\theta_{w,t} &= \varepsilon_{w,t}, \quad 0 \le \rho_w \le 1, && (9)\\
(1 - \rho_g L)\theta_{g,t} &= \varepsilon_{g,t}, \quad 0 \le \rho_g \le 1, && (10)
\end{aligned}
$$

$$
\begin{aligned}
\varepsilon_t &\sim iid(0, \mathrm{Diag}(\sigma_l^2, \sigma_y^2, \sigma_e^2, \sigma_w^2, \sigma_g^2)), && (11)\\
\theta_{l,0} &= \theta_{y,0} = \theta_{e,0} = \theta_{w,0} = \theta_{g,0} = 0. && (12)
\end{aligned}
$$

NOTE: L is the lag operator: $Lx_t = x_{t-1}$.

TABLE 2: Four examples with an exogenous labor force ($\alpha = 0$).

	Case 1		Case 2		Case 3		Case 4	
	$\beta = 1$		$\gamma_1 = 1$, $\delta = 1$		$\delta = \gamma_2 = 0$, $\gamma_1 = \beta^{-1} \neq 1$		$\delta = 0$, $\gamma_2 > \gamma_1(1 - \beta)$, $\gamma_1 > \beta^{-1}$	
	θ_y	θ_l	θ_y	θ_l	θ_y	θ_l	θ_y	θ_l
$y - e$	1	0	1	$\beta - 1$	β^{-2}	0	$\beta^{-1}\frac{\beta\gamma_2+\beta-1}{\gamma_2+(\beta-1)\gamma_1}$	$\frac{(\beta-1)\gamma_2}{\gamma_2+(\beta-1)\gamma_1}$
e	$\frac{1-\gamma_1}{\gamma_2}$	1	0	1	0	0	$\beta^{-1}\frac{1-\beta\gamma_1}{\gamma_2+(\beta-1)\gamma_1}$	$\frac{\gamma_2}{\gamma_2+(\beta-1)\gamma_1}$
$l - e$	$\frac{\gamma_1-1}{\gamma_2}$	0	0	0	0	1	$\beta^{-1}\frac{\beta\gamma_1-1}{\gamma_2+(\beta-1)\gamma_1}$	$\frac{(\beta-1)\gamma_1}{\gamma_2+(\beta-1)\gamma_1}$
$w - p$	1	0	β^{-1}	0	β^{-1}	0	β^{-1}	0
$w - q$	1	0	1	$\beta - 1$	β^{-1}	0	β^{-1}	0

TABLE 3: The definitions of the 0/1 dummy variables.

Dummy	WWI	D1919	WWII	D1945	STATE	OILI	OILII
= 1 in	1914-1919	1919	1940-1946	1945	1964-1979	1973-1992	1979-1992

TABLE 4: Likelihood ratio tests of the number of common trends.

k	LR_{tr}	95% crit. value	p-value
5	138.90	37.65	0.00
4	61.32	26.30	0.00
3	21.86	16.92	0.01
2	8.35	9.48	0.08
1	2.06	3.84	0.15

NOTE: The LR_{tr} statistics have been calculated with a degrees of freedom correction as suggested by Reimers (1992). The inclusion of (at least) four dummy variables in the VAR (with no restrictions on the coefficients on these dummies) implies that the limiting distributon of the test statistic is χ^2 with k^2 degrees of freedom; k is the number of common trends under the null hypothesis.

TABLE 5: Tests of stationarity.

Stationarity of	LR statistic	p-value
$(y_t - e_t) - (\beta - 1)e_t$	6.69	0.04
$l_t - \alpha(w_t - q_t)$	8.18	0.02
$w_t + e_t - p_t - y_t \wedge l_t - e_t \wedge q_t - p_t$	41.56	0.00
$w_t + e_t - p_t - y_t$	8.52	0.01
$l_t - e_t$	8.90	0.01
$q_t - p_t$	6.38	0.04

NOTE: The limiting distribution of the LR statistics is χ^2 with degrees of freedom equal to the number of overidentifying restrictions.

TABLE 6: The estimated structural long run relations.

$$\underset{(0.168)}{l_t = 0.606}\,(w_t - q_t) + \theta_{l,t}, \qquad \sigma_l = \underset{(0.001)}{0.006},$$

$$y_t - e_t = -0.054\, e_t + \theta_{y,t}, \qquad \sigma_y = \underset{(0.003)}{0.011},$$

$$e_t = \underset{(0.006)}{1.057}\, y_t - (w_t - p_t),$$

$$w_t - q_t = \underset{(0.008)}{1.072}\,(y_t - e_t) - \underset{(0.031)}{0.085}\,(l_t - e_t),$$

$$q_t - p_t = \underset{(0.051)}{-0.341}\,(p_t - w_t - e_t + y_t).$$

NOTES: Estimated asymptotic (conditional) standard errors are reported within parentheses. LR test of overidentifying restrictions: $\chi^2(2) = 2.85$, p-value = 0.24.

TABLE 7: Estimated common trends coefficients.

Estimated common trends coefficients (*in percent*)				
	$\delta \neq 0$		$\delta = 0$	
variable	θ_y	θ_l	θ_y	θ_l
$y - e$	1.036	-0.059	0.929	-0.128
	(.243)	(.011)	(.199)	(.034)
e	0.434	1.094	0.440	1.321
	(.377)	(.211)	(.516)	(.352)
$l - e$	0.228	-0.507	0.270	-0.474
	(.150)	(.098)	(.152)	(.127)
$w - p$	1.120	0.000	1.075	0.000
	(.267)	(–)	(.247)	(–)
$w - q$	1.091	-0.020	1.075	0.000
	(.258)	(.004)	(.247)	(–)
$w + e - (y + p)$	0.084	0.059	0.147	0.128
	(.032)	(.011)	(.067)	(.034)

NOTES: Estimated asymptotic standard errors are reported within parentheses. The asymptotic distribution of the estimated common trends coefficients is Gaussian and given in Warne (1993).

TABLE 8: Forecast error variance decompositions.

Var.	Inno.	Horizon 1	2	3	4	8	12	∞
	ε_y	0.280	0.493	0.612	0.638	0.689	0.722	0.997
		(0.212)	(0.172)	(0.187)	(0.200)	(0.210)	(0.224)	(0.002)
$y-e$	ε_l	0.003	0.007	0.008	0.032	0.039	0.041	0.003
		(0.018)	(0.025)	(0.035)	(0.087)	(0.098)	(0.104)	(0.002)
	$\varepsilon_e, \varepsilon_w, \varepsilon_g$	0.717	0.500	0.381	0.330	0.272	0.237	0.000
		(0.213)	(0.188)	(0.208)	(0.227)	(0.205)	(0.202)	(–)
	ε_y	0.008	0.014	0.014	0.012	0.075	0.091	0.136
		(0.036)	(0.032)	(0.034)	(0.034)	(0.068)	(0.101)	(0.195)
e	ε_l	0.614	0.756	0.785	0.779	0.779	0.807	0.864
		(0.173)	(0.141)	(0.127)	(0.111)	(0.092)	(0.132)	(0.195)
	$\varepsilon_e, \varepsilon_w, \varepsilon_g$	0.378	0.230	0.201	0.209	0.145	0.102	0.000
		(0.186)	(0.131)	(0.109)	(0.092)	(0.070)	(0.069)	(–)
	ε_y	0.035	0.032	0.034	0.039	0.030	0.055	0.168
		(0.135)	(0.067)	(0.073)	(0.095)	(0.084)	(0.165)	(0.209)
$l-e$	ε_l	0.788	0.845	0.865	0.868	0.875	0.869	0.831
		(0.255)	(0.104)	(0.093)	(0.110)	(0.093)	(0.172)	(0.209)
	$\varepsilon_e, \varepsilon_w, \varepsilon_g$	0.177	0.123	0.102	0.093	0.095	0.076	0.000
		(0.176)	(0.061)	(0.037)	(0.032)	(0.054)	(0.062)	(–)
	ε_y	0.580	0.765	0.823	0.803	0.793	0.798	1.000
		(0.164)	(0.099)	(0.082)	(0.113)	(0.123)	(0.143)	(–)
$w-p$	ε_l	0.142	0.067	0.041	0.061	0.071	0.074	0.000
		(0.193)	(0.091)	(0.054)	(0.092)	(0.116)	(0.139)	(–)
	$\varepsilon_e, \varepsilon_w, \varepsilon_g$	0.278	0.169	0.136	0.135	0.136	0.127	0.000
		(0.100)	(0.060)	(0.060)	(0.071)	(0.077)	(0.078)	(–)
	ε_y	0.856	0.848	0.864	0.814	0.813	0.816	1.000
		(0.110)	(0.074)	(0.055)	(0.090)	(0.106)	(0.129)	(0.000)
$w-q$	ε_l	0.110	0.054	0.034	0.057	0.057	0.062	0.000
		(0.116)	(0.066)	(0.030)	(0.067)	(0.086)	(0.105)	(0.000)
	$\varepsilon_e, \varepsilon_w, \varepsilon_g$	0.034	0.098	0.102	0.129	0.130	0.122	0.000
		(0.045)	(0.049)	(0.048)	(0.066)	(0.068)	(0.069)	(–)
	ε_y	0.049	0.066	0.155	0.195	0.217	0.238	0.646
		(0.113)	(0.067)	(0.127)	(0.167)	(0.248)	(0.322)	(0.170)
$w+e-(y+p)$	ε_l	0.151	0.136	0.109	0.105	0.109	0.121	0.354
		(0.143)	(0.105)	(0.081)	(0.080)	(0.101)	(0.159)	(0.170)
	$\varepsilon_e, \varepsilon_w, \varepsilon_g$	0.800	0.798	0.736	0.701	0.674	0.640	0.000
		(0.173)	(0.139)	(0.171)	(0.197)	(0.281)	(0.384)	(–)

NOTES: The estimated standard errors are reported within paranthesis. The limiting distribution of the estimated variance decompositions is Gaussian; see Warne (1993).

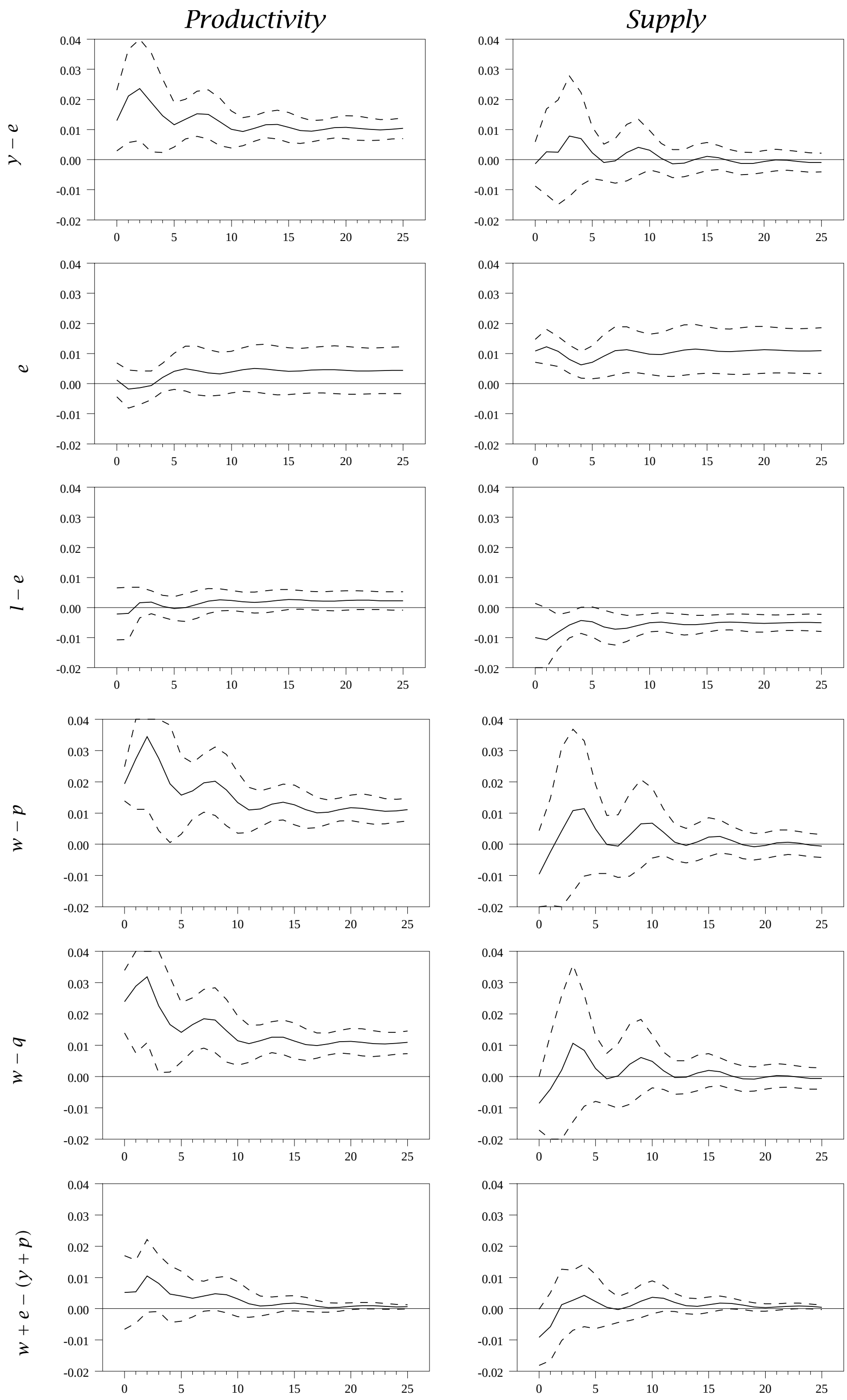

FIGURE 1: Responses to unit shocks in labor productivity and supply.

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