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TESTING WEAK EXOGENEITY BY MULTIVARIATE COINTEGRATION TECHNIQUES: THE DEMAND FOR LABOUR IN FINNISH MANUFACTURING*

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The study examines the efficiency of the single-equation approach in modelling employment determination in the context of Finnish labour market data. The task is accomplished by using the multivariate cointegration techniques developed in Johansen (1988) and Johansen and Juselius (1990). The results suggest that the weak exogeneity of the conventional conditioning variables, including output, capital stock, wages, product prices and material prices cannot be taken for granted. The possibility of the loss of information involved in contemporaneous conditioning implies that care should be taken in applying single-equation methods to Finnish labour market data. (JEL C10, J23)

1. Introduction

The bulk of empirical labour demand analysis has been carried out in the framework of single-equation estimation methods.[1] One limitation of this approach is that it requires all the explanatory variables to be weakly exogenous with respect to the parameters of interest, i.e., there is no loss of information involved in the conditioning of the model. In this study we depart from this conventional approach and make use of a full system of equations therefore allowing for possible interactions in the determination of employment, output, capital stock and certain price variables. In particular, we examine the labour demand schedule in the framework of a multivariate error-correction model, pioneered in Johansen (1988) and Johansen and Juselius (1990). The main purpose of the study is, using data on the Finnish manufacturing sector, to examine whether the single-equation approach yields efficient estimates on the long-run parameters of the labour demand schedule. The rest of the paper is organized as follows. Section 2 provides a theoretical base for the empirical analysis. Section 3 outlines the Johansen ML-estimation procedure. Section 4 describes the data and reports the test results regarding weak exogeneity and certain structural hypotheses. Section 5 concludes the study.

2. Theoretical considerations

We begin the exposition with a standard static production relation,

$$(1) \qquad Q_t = f(N_t, R_t, C_t, A_t)$$

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[1] *See, e.g. Hamermesh (1986) and Nickell (1986) and references therein.*

where Q_t is (gross) output in period t, N_t is employment, R_t is raw materials, C_t is (predetermined) capital stock, and A represents technical progress. In order to account for different hypotheses concerning the structure of the product market, the labour demand equation is written in the following general form:

$$(2) \quad N_t^* = g(W_t, P_t, M_t, Y_t, C_t, A_t)$$

where N_t^* is desired employment in period t, W_t is nominal wage costs, P_t is the product price deflator, M_t is the price of raw materials and Y_t is a demand shift variable.[2] To make the equation dynamic we introduce adjustment costs which make it unprofitable for firms to adjust employment immediately to the current desired level N^*. Conventional formulations for adjustment costs capture costs of two types: costs arising from being out of equilibrium and those arising from adjusting the level of employment. The expected discounted present value of these costs can be written as

$$(3) \quad C_t = E_t\{\textstyle\sum_{i=0}^{\infty} r^i(\delta_1(N_{t+i} - N_{t+i}^*)^2 + \delta_2(N_{t+i} - N_{t+i-1})^2)\}$$

where r is the discount factor and E is the expectation operator. The solution to this optimisation problem is of the following form (see, e.g., Nickell, 1986)

$$(4) \quad N_t = \gamma_1 N_{t-1} + \gamma_1 \textstyle\sum_{i=0}^{\infty} \left(\frac{1}{\gamma_2}\right)^i N_{t+i}^*$$

which depicts current employment as a function of the previous period's employment plus a weighted sum for all future levels of desird employment. As Sargent (1979) shows, γ_1 and γ_2 are functions of r, δ_1 and δ_2 such that $\gamma_1 < 1 < \gamma_2$. Substituting equation (2) into (4), we obtain a dynamic forward-looking employment equation of the form

$$(5) \quad N_t = \gamma_1 N_{t-1} + \gamma_1 \textstyle\sum_{i=0}^{\infty} \left(\frac{1}{\gamma_2}\right)^i g\left[\left(W_{t+i}, P_{t+i}, M_{t+i}, Y_{t+i}, C_{t+i}, A_{t+i}\right)\right]$$

[2] *The formulation covers the following cases: a price-taking firm (output price is exogeneous), a monopolistic firm (output is exogeneous) and a demand constrained firm (both the output price and output are exogenous).*

To make the estimation of the model possible we assume that expectations can be captured by autoregressive processes. The procedure of using a backward-looking model for output is conventional; see, e.g. Harvey et al (1986).[3] As far as the factor price terms are concerned, we apply similar strategy. In short, the labour demand equation can be written in the following form:

$$(6) \quad N_t = \pi_0 + \pi_1 N_{t-1} + \textstyle\sum_{i=0}^{l} \pi_{2i} Y_{t-i} + \sum_{i=0}^{l} \pi_{3i} W_{t-i} + \sum_{i=0}^{l} \pi_{4i} P_{t-i} + \sum_{i=0}^{l} \pi_{5i} M_{t-i} + \sum_{i=0}^{l} \pi_{6i} C_{t-i} + \pi_7 t + \eta_t$$

where technical progress is proxied by a linear time trend t and η_t is a stochastic disturbance term.

3. *Estimation methods*

The study employs multicointegration ML-estimation methods developed and applied in Johansen (1992) and Johansen and Juselius (1990, 1992). The labour demand schedule given in (6) can be represented as a part of VAR(k) model

$$(7) \quad \Delta Z_t = \Gamma_1 \Delta Z_{t-1} + \ldots + \Gamma_{k-1} \Delta Z_{t-k+1} + \Pi Z_{t-1} + \mu + D_t + \varepsilon_t; \quad t = 1 \ldots T$$

where $\Gamma_i = -(1 - \Pi_1 + \ldots + \Pi_i) i = 1 \ldots k-1$, and $\Pi = -(1 - \Pi_1 + \ldots + \Pi_k)$. Z_t is a q-dimensional vector of stochastic variables, Γ_i are $q \times q$ matrices of the short-run coefficients and Π is a $q \times q$ matrix of the long-run coefficients. In our case $Z_t = (N, Y, W, P, M, C)'$ and thus q = 6. μ is the intercept vector (allowing for the possibility of a common deterministic trend in the non-stationary part of the process), D_t stands for (s-1) -dimensional column vector zero-mean seasonal dummies (s is the seasonal period), and ε is an i.i.d. Gaussian

[3] *There are two other well-known approaches for dealing with the result that future expectations enter the employment equation, viz. (i) the approach based on the use of survey data, see, e.g. Wren-Lewis (1986) and Pehkonen (1992), and (ii) the approach based on the rational expectations hypothesis, see e.g. Sargent (1978), Henry and Wren-Lewis (1984) and Ilmakunnas (1989).*

random vector.[4] If rank $p(\Pi) = 0$, (7) is a standard VAR model in first-difference form and no cointegration exists in the data. If Π is of full rank, i.e. $p(\Pi) = q$, all Z_t series are stationary. If there is a reduced rank such that $p(\Pi) = r < q$, Z_t has r cointegration vector and q-r common stochastic trends. In this case the Π matrix can be written as $\Pi = \alpha\beta'$ where α and β are of dimension $q \times r$. β represents the cointegration vectors and α the weights attached to them in each of the equations of the VAR. In order to illustrate the role of conditioning we rewrite (7) in the following form (see, e.g., Juselius, 1991)

$$(8)\quad \begin{bmatrix}\Delta Y\\ \Delta X\end{bmatrix}_t = \Gamma_1 \begin{bmatrix}\Delta Y\\ \Delta X\end{bmatrix}_{t-1} + \begin{bmatrix}\alpha_{11} & \alpha_{12}\\ \alpha_{21} & \alpha_{22}\end{bmatrix}\begin{bmatrix}\beta_{11} & \beta_{12}\\ \beta_{21} & \beta_{22}\end{bmatrix} Z_{t-1} + \begin{bmatrix}\mu_1\\ \mu_2\end{bmatrix} + \begin{bmatrix}D_1\\ D_2\end{bmatrix} + \begin{bmatrix}\varepsilon_1\\ \varepsilon_2\end{bmatrix}_t$$

where the vector Z_t is partitioned into the jointly stochastic variables Y_t and the weakly exogenous variables X_t. If the zero restriction $\alpha_{21} = \alpha_{22} = 0$ cannot be rejected, and the parameters of interest are the long-run coefficients in β, it is valid to condition on the marginal distribution of ΔX_t and to analyse the system of ΔY equations of the form

$$(9)\quad \Delta Y_t = \overline{\Gamma}_0 \Delta X_t + \overline{\Gamma}_1 \Delta Z_{t-i} + \alpha\beta' Z_{t-1} + \mu + D + \varepsilon_t$$

i.e. the weak exogeneity of, says h variables with respect to β allow the reduction of the system from q to q–h without loss of efficiency.

4. Empirical results

The study examines quarterly data on Finnish manufacturing. The sample covers the period from 1960.1 to 1991.4. A visual inspection of the graphs depicted in Figures 1–7 suggests, to some extent, that differenced series are stationary, i.e. they are integrated of order 1. This interpretation is supported by the Dickey-Fuller test results reported in Appendix 1.

We begin the analysis by examining the full model given by equation (7). Cointegration analysis requires that the disturbances are white noise. This can be achieved by the choice of an appropriate lag length (k) and, if required, through the introduction of dummy variables accounting for outliers in the data set.[5] The misspecification test results for the full model with k = 2 are reported in Table 1. The residuals of the VAR system are largely acceptable, although some problems exist. In particular, the product price and material price equations fail the ARCH test and the residuals of the capital stock equation and material price equation display non-normality.

Table 1. Residual misspecification tests

Equation	B-P.Q (31)/29	ARCH (2)	SKEW.	EX.KURT.	J-B.
Δn	1.740	2.188	–.315	–.013	1.953
Δy	1.998	2.599	–.200	.199	.979
Δw	1.484	4.930	–.209	–.054	.871
Δp	1.278	12.117**	.121	.679	2.554
Δm	1.354	16.812**	–.171	1.435	10.703**
Δc	1.337	1.001	.594	.858	10.555**

Notes: * = significant at five per cent level; ** = significant at one per cent level

The rank test is performed using the likelihood ratio tests employed, among others, in Johansen and Juselius (1990). Two statistics known as the trace statistic (trace) and the maximal eigenvalue statistic (lambda) are reported in Table 2. The statistics allow us to determine the rank of cointegration (r) and the number of common

[4] *In the case of labour market data technical progress provides a potential source for a trend. This issue is taken up as we proceed.*

[5] *Calculations are performed by using CATS in RATS (see Juselius, 1991). The VAR model includes four dummy variables: D67 is a dummy for the stabilization period followed by the devaluation in 1967Q3 (it obtains a value 1 in 1968Q1-68Q4 and 0 otherwise); D71 is a dummy for the three-week strike in the metal industry in 1971Q1 (1 in 1971Q1, 0 otherwise); D73 is a dummy for the first oil shock (1 in 1974Q1-74Q2, 0 otherwise); DWAGE is a multiplicative dummy which captures the timing of centralized wage agreements, see Tyrväinen (1989) for details.*

factors (q-r). The test statistics are compared to the 95 per cent quantiles of the appropriate limiting distribution. The critical values are taken from Osterwald-Lenum (1992). The hypothesis that r = 0 is rejected by the trace test as well as the lambda test, whereas the hypothesis that $r \leq q$, q = 3...5 cannot be rejected. The results as to whether the number of cointegration vectors is 1 or 2 are not, unfortunately, conclusive. In particular, the lambda test supports the choice of r = 1, implying that there is one stationary relation and four common trends in the data set, whereas the trace test suggests that there are two stationary vectors and three common trends in the data set, i.e. that r = 2.[6]

Table 2. Cointegration rank tests

Eigenvalue	0.310	0.205	0.162	0.115	0.061	0.000
Hypotheses	r = 0	r ≤ 1	r ≤ 2	r ≤ 3	r ≤ 4	r ≤ 5
Trace statistics	113.71	69.90	42.76	21.97	7.50	0.04
95 % quantiles	94.15	68.52	47.21	29.68	15.41	3.76
Lambda statistics	43.80	27.13	20.78	14.47	7.45	0.04
95 % quantiles	39.37	31.46	27.07	20.97	14.07	3.76

Notes: Critical values are taken from Osterwald-Lenum (1992), Table 1.

We continued the analysis with the perception that is consistent with our maintained hypothesis: there is just one cointegrating vector among the variables. Considering the restricted cointegration space and normalizing the cointegrating vector on n, we obtain (lower-case letters denote logarithms of the original variables):

$$(10) \quad n_t = 0.66y_t - 1.02w_t + 0.92p_t - 0.01m_t + 0.78c_t + \lambda_1 D_t$$

which, by introducing two further restrictions (accepted by the data), can be rewritten as

$$(10') \quad n_t = 0.62y_t - 0.98(w_t / p_t) + 0.37c_t + \lambda_2 D_t$$

Although (10') is largely consistent with previously reported employment equations, its interpretation is unclear since the imposed normalization is arbitrary.[7] The appropriateness of the normalization can be tested by examining the status of the variables (endogeneity versus exogeneity) with respect to the long-run parameters of the cointegrating vector. In the system approach a test of the exogeneity of a subset of the variables for long-run parameters is based on the inspection of adjustment parameters α. In our case the null hypothesis (H_0) to be tested is

$$H_0: \quad \alpha_n \neq 0 \text{ and } \alpha_j = 0; \quad j = y, w, p, r, c$$

If the H_0 cannot be rejected, the reduction of the system to a one-dimensional model and the normalization imposed in (10) are appropriate.

The likelihood ratio test results reported in Table 3 indicate that weak exogeneity of employment with respect to the long-run parameters is to be rejected, as expected. Furthermore, we are unable to reject weak exogeneity for output, wages and raw materials. On the other hand, the tests indicate that product prices p and capital stock c may not be weakly exogeneous. The results thus provide only a limited support for the interpretation that the normalization put forward in (10) is valid and the single-equation approach yields efficient estimates on the long-run parameters of the labour demand schedule. This interpretation is supported by the result of the joint test which imposes all restrictions simultaneously: the maintained hypothesis that y, w, p, m and c are jointly as weakly exogenous and n is endogenous with respect to β is rejected; see column 7 of Table 3.

Table 3. Tests of weak exogeneity

χ^2-test for weak exogeneity						
α_n	α_y	α_w	α_p	α_m	α_c	α_j
6.51**	1.96	0.17	5.13**	0.78	5.11**	24.41**

Notes: ** = significant at one per cent level.

[6] *The absence of trend was tested by the likelihood ratio test* $c_c = -T\sum_{r+1}^{q}\ln(1-\lambda_i^*)/(1-\hat{\lambda}_i)$ *where* λ_i^* *and* $\hat{\lambda}_i$ *refer to eigenvalues under the null (no trend) and the alternative, respectively; for details see Johansen and Juselius (1990). The hypothesis that the linear trend is absent was rejected:* $c_c(5) = 19.1 \geq c^*_{0.05}(5) = 11.1$ *The same test result is obtained by the testing procedure suggested in Johansen (1992).*

[7] *See e.g. Tyrväinen (1992), Pehkonen (1990) and Santamäki (1986).* D_t *refers to deterministic variables including seasonal and intervention dummies as well as a linear trend capturing the role of technical progress.*

Since the results concerning the rank of cointegration were not clear-cut (in addition that the power of cointegration tests may be low), we continued the analysis by considering the case where $r = 2$ and examining whether the choice yields cointegration vectors which can be given economically meaningful interpretations. The inspection of the β-vectors suggested that the first vector can approximately be described as:

$$(11) \quad w_t / p_t = 0.90(y_t / n_t) + \lambda_3 D_t$$

and the second vector as:

$$(12) \quad n_t / c_t = 0.38 y_t - 1.00(w_t / m_t) + \lambda_4 D_t$$

The first vector seems to constitute a (suppressed) real wage equation where wages are related to productivity, whereas the second vector describes a labour demand equation *á* la Layard and Nickell (1992).[8] These results thus enhance the view that there is loss of information involved in the conditioning of employment by output, capital stock and price variables.

The results reported above must, however, be interpreted with care for two reasons. First, as noted above, residuals of the VAR model were not strictly Gaussian. This suggests that the robustness of the results should be checked with respect to the chosen set of interventions as well as to alternative lag-structures for short-run dynamics. Second, apart from theoretical considerations, there is a considerable amount of arbitrary in the set of variables analyzed in this study.[9] In particular, it is possible that the apparent endogeneity of the product price and capital stock variables can be explained by omitted variables related to price and capital formation.[10]

For these reasons we continued the analysis by considering the following alternatives to the basic employment equation. First, the capital stock variable was replaced by a variable mimicking the user cost of capital. This modification is according to (long-run) employment equations which regard capital stock as a variable input. Second, both variables were excluded from the model. As in the case above, this modification is also commonly made: these variables are often omitted because their empirical counterparts are considered inadequate. Third, experiments with a lag-structure $k = 3$ and $k = 4$ were carried out. Fourth, we examined whether it is possible that the augmented wage variable (including social security payments) imposes an implicit structure which prevents the emergence of the other cointegration vectors.[11]

Table 4. Alternative specifications

Specification	A	B	C	D	E
Sample period	1962.1–1991.4	1962.1–1991.4	1970.1–1991.4	1970.1–1991.4	1970.1–1991.4
Lag-structure k	2	2	2	2	2
No. of vectors r	1	1	1	1	1
Eigenvalue λ	0.285	0.252	0.386	0.356	0.340
Exogeneity tests (p-values)					
$\alpha_n = 0$	0.01	0.01	0.07	0.01	0.02
$\alpha_y = 0$	0.03	0.10	0.00	0.03	0.01
$\alpha_w = 0$	0.15	0.29	0.03	0.97	0.16
$\alpha_p = 0$	0.34	0.21	0.64	0.13	0.72
$\alpha_m = 0$	0.43	0.13	0.86	0.35	0.39
$\alpha_c = 0$	–	–	–	0.08	–
$\alpha_i = 0$	0.54	–	0.91	–	–
$\alpha_j = 0$	0.06	0.03	0.01	0.03	0.04
Normalized cointegration vectors					
n	1.00	1.00	1.00	1.00	1.00
y	–1.73	–1.81	–0.52	–0.52	–0.70
w	1.38	1.33	0.78	0.83	0.74
p	–1.24	–0.83	–1.01	–0.48	–0.58
m	0.10	–0.13	0.25	–0.23	–0.07
c	–	–	–	–0.62	–
i	0.02	–	0.08	–	–
Restricted β-vector					
$\beta_n = -\beta_y$ and $\beta_w = -\beta_p$ (p – values)	0.08	0.03	0.28	0.02	0.39

[8] *The restrictions are data-admissible:* $\chi(5) = 10.10$ *implying a p-value 0.07. There are two points concerning the coefficient on the relative price variable which are worth noting. First, the coefficient is of rather considerable magnitude, thus suggesting possible misspecification due to omitted variables. Second, if the equation is estimated in an unrestricted form, the coefficient on the material price variables is not well-determined and it can be omitted from the equation.*

[9] *Needless to say, the same remark applies to the empirical counterparts of the theoretical variables.*

[10] *Naug and Nymoen (1993), who examine import price adjustment in the context of Norwegian data, conclude that the apparent endogeneity of the labour costs variable in the import price equation is due to omitted variables since it is not supported by an alternative test based on a marginal model for the variable in question.*

[11] *Tyrväinen's (1992) study analyzing labour market data on Finnish manufacturing detects three cointegrating relations amongst the 9 variables considered.*

Appendix 1. The ADF (1) results

Order	I(0)		I(1)	
Variable	no trend	trend	no trend	trend
n	–1.19	–5.90*	–11.72*	–11.68*
y	–2.36	–1.78	–21.04*	–22.67*
w	4.72	1.48	–9.62*	–13.17*
p	0.54	–2.37	–3.56*	–3.54*
i	0.10	–1.66	–7.32*	–7.33*
m	–1.50	–2.71	–3.57*	–3.69*
c	–0.90	–3.03	–3.06*	–3.08

Notes: * = Significant at (at least) five per cent level.

Fifth, the period covering 1970.1–1991.4 was taken as the basis of the estimation. The advantage of the last-mentioning modification is that it allows the results to be compared with those of Tyrväinen (1992). The main results of these specification checks are summarized in Table 4.

There is four points regarding these specification experiments which must be noted. First, the results about the number of stationary vectors among the variables were, as above, somewhat inconclusive although they appeared to be more in favour of the notion that there is only one cointegrating vector in the data set. Consequently, we focused our attention on those cases where both tests supported the choice $r = 1$. Second, the tests for the residuals of the alternative VAR models with $k = 2$ suggested that the assumptions of i.i.d. errors are not badly violated and that a longer lag-structure ($k = 3$ or $k = 4$) yield no apparent changes to the results. This result was, in particular, true for the shorter investigation period. Third, as far as the whole sample is concerned, the inclusion of the user cost variable (specification A) or its exclusion along the capital stock variable (specification B) seems to yield results which are at variance with the a-priori beliefs, the parameter estimates on the price variables and the demand shift variable being, to some extent, of excessive magnitude. Fourth, the exclusion of the capital stock variable or the consideration of the shorter investigation period suggests an interesting switch in the results. In the case of the basic model weak exogeneity was rejected for the product price variable but not for the output variable. Now, the reverse is true.

The results of Table 4 imply the rejection of the maintained hypothesis in all cases excluding the specification A; see the test statistic for the joint test $\alpha_j = 0$. As far as the individual tests are concerned, weak exogeneity of output, i.e. the restriction that $\alpha_y = 0$, is rejected in specifications A, C, D and E. The results thus imply that the hypothesis of output being weakly exogenous for the parameters of the co-integrating vector cannot be accepted. The results are not, however, utterly discouraging since the cointegration regression appears to identify a marginal productivity condition in which the ratio of output and employment (y/n) is explained by, among other variables, the real labour costs (w/p). This result is confirmed by the specifications A, C and E and discarded by the specifications B and D; see the test statistics for the joint test imposing the restrictions $\beta_y = -\beta_n$ and $\beta_w = -\beta_p$.[12] Furthermore, the more stringent hypothesis that there is one-to-one relationship between productivity and real wages cannot be rejected in specifications C and E. As far as the parameters of the cointegrating vector for the latter investigation period are concerned, it is interesting to compare the results to those by Tyrväinen (1992). Although the long-run elasticity estimates are qualitative similar rather large discrepancies between the figures[13] suggest that the assumption that there is only one cointegrating vector in the data set is too restrictive thus undermining support for the view that the single-equation approach yields efficient estimates on the long-run parameters of the labour demand schedule.

As far as the theoretical models concerning the functioning of the Finnish labour market are concerned, a recent study by Holm et al (1994) provides an interesting basis for some remarks. In their study Holm et al. construct a theoretical trade union model on wage, employment and capital determination which yields a three equation system where the wage and the capital stock are exogenous in the labour demand equation, the wage variable is endogenous in the capital stock equation, and the capital stock is endogenous in the wage equation. To be precise, the model is based on a two-stage game where the union and firms first negotiate on wages and the level of capital stock, respectively, employment being then determined on the

[12] *The test on the β-vector is conducted under the hypothesis that the adjustment parameters α_i:s excluding α_n and α_y are zeros.*

[13] *Tyrväinen's results imply that for the real labour cost the coefficient is around –0.2 (here –0.7) and for output around 0.3 (here around 0.6).*

basis of profit maximizing behaviour of the firms. Since the present study detects at most only two cointegration vectors, labelled a labour demand equation and a wage equation, comparison becomes, unfortunately, rather difficult. If, however, the assumption that there are two cointegration vector in the data set can be maintained, the equations (11) and (12) suggest a slightly different explanation on the underlying model determinating wages, employment and capital stock compared to that put forward in Holm et al. In particular, the present results are consistent with a two-stage trade union model where the union and firms first decide on wages and after that the firms determine the optimal employment-capital ratio. The question on the underlying model generating the data remains, however, unsettled since the results from the analysis with one cointegrating vector provide support for both views: in some cases capital stock appears to be exogenous in the labour demand equation (thus being consistent with the HHK-model), whereas in some cases it appears to be endogenous.

5. Conclusions

The purpose of this study was to examine the validity of the single-equation approach in modelling employment determination in the context of Finnish labour market data. The task was accomplished by using multicointegration techniques developed in Johansen (1988) and Johansen and Juselius (1990). The Johansen procedure provides a convenient framework for testing weak exogeneity, an issue which is crucial for efficient inference in a conditional model.

The results for the period 1960.1–1991.4 provided no support for the view that it is legitimate to use the single-equation approach in estimating the parameters of the labour demand equation. The robustness of the interpretation that there is loss of information involved in the conditioning of employment by output and price variables was further enhanced by the experiments using a shorter investigation period and alternative specifications. In a number of alternative cases, however, the interpretation of the cointegrating vector was in line with the labour demand schedule: the analysis detected a marginal productivity condition in which real product wages adjust (one-to-one) with productivity. As far as the theoretical models on wage and employment determination are concerned, the results are, to some extent, consistent with a two-stage trade union model where the union and the firm first negotiate on wages and after that the firms choose its optimal capital-labour ratio.

The evidence reported in the study cannot, however, be regarded conclusive. In particular, the robustness of the results should be assessed in the light of the following remarks. First, the lag-length $k = 2$ for the residual misspecification tests is arbitrary, although our experiments implied that the main conclusions reported in this paper are not affected by the choices $k = 3$ or $k = 4$. Second, the residual specification checks with respect to the intervention dummies carried out in the study were at best very preliminary. Similarly, the robustness of the results with respect to the empirical counterparts of the theoretical variables require a further analysis. This remark applies to the proxies for the user cost of capital and the demand shift variable in particular. Third, since this study makes use of only one data set at a rather highly aggregated level, more research is required to generalize these results. An obvious extension of the study would be to apply the multicointegration approach to industry level data.

References

Hamermesh, D. (1986). "The demand for labour in the long run." In *Handbook of Labour Economics*, Vol 1, 429–469. Eds. R. Layard, and O. Ashenfelter, Amsterdam: North-Holland.

Harvey, A., S:G:B: Henry, S. Peters, and S. WrenLewis (1986). "Stochastic trends in dynamic regression models: An application to the employment-output equation." *Economic Journal*, 96, 975–986.

Henry, S.G.B., and S. Wren-Lewis (1984). "The aggregate labour market in the U.K.: Some experiments with rational expectations models." In *Contemporary Macroeconomic Modelling*. Eds. P. Malgrange, and P. Muet. Oxford: Basil Blackwell.

Holm, P., S. Honkapohja, and E. Koskela (1994). "A monopoly union model of wage determination with capital and taxes: An empirical application to the Finnish manufacturing." *European Economic Review*, 38, 285–304.

Ilmakunnas, P. (1989). "Survey expectations vs rational expectations in the estimation of a dynamic model: Demand for labour in Finnish manufacturing." *Oxford Bulletin of Economics and Statistics*, 51, 297–313.

Johansen, S. (1992). "Determination of cointegration rank in the presence of a linear trend." *Oxford Bulletin of Economics and Statistics*, 54, 383–397.

— **(1992).** "Testing weak exogeneity and the order of cointegration in UK money demand data." *Journal of Policy Modeling*, 14 (3) 313–334.

Johansen, S., and K. Juselius (1990). "Maximum likelihood estimation and inference on cointegration – with applications to the demand for money." *Oxford Bulletin of Economics and Statistics*, 52 (2), 169–210.

— **(1992).** "Testing structural hypotheses in a multivariate cointegration analysis of the PPP and the UIP for UK." *Journal of Econometrics*, 53, 211–244.

Juselius, K. (1991). Manual to cointegration analysis of time series. Institute of Economics, University of Copenhagen.

Naug, B., and R. Nymoen (1993). Import price adjustment and pricing to market: A test on Norwegian data. Mimeo, Central Bureau of Statistics, Oslo.

Layard, R., S. Nickell, and R. Jackman (1992). *Unemployment: Macroeconomic performance and the labour market.* Oxford: Oxford University Press.

Nickell, S. (1986). "Dynamic models of labour demand." In *Handbook of Labour Economics*, Vol 1, 473–552. Eds. R. Layard, and O. Ashenfelter, Amsterdam: North-Holland.

Osterwald-Lenum, M. (1992). "A note with quantiles of the asymptotic distribution of the maximum likelihood cointegration rank test statistics." *Oxford Bulletin of Economics and Statistics*, 54 (3), 461–471.

Pehkonen, J. (1992). "Survey expectations and stochastic trends in modelling the employment – output relationship." *Oxford Bulletin of Economics and Statistics*, 54, 579–589.

— **(1990).** "Trade union objectives and cyclical variability of wages and employment." *Scandinavian Journal of Economics*, 92 (4) 573–586.

Santamäki, T. Empirical research on the demand for labour function in Finland, Ministry of Labour, Komiteamietintö No 40, Helsinki.

Sargent, T. (1979). *Macroeconomic Theory.* New York: Academic Press.

— **(1978).** "Estimation of dynamic labour demand schedules under rational expectations." *Journal of Political Economy*, 86, 1009–1044.

Tyrväinen, T. (1989). "A guide to the Finnish labour market." *Finnish Economic Papers*, 2 (2), 134–146.

— **(1992).** Wage setting, taxes and demand for labour: multivariate analysis of the cointegrating relations. Bank of Finland Discussion Papers No. 22.

Wren-Lewis, S. (1986). "An econometric model of U.K. manufacturing employment using survey data on expected output." *Journal of Applied Econometrics*, 1, 297–316, 1986.

Data Appendix: Data and definitions

n = log of Finnish manufacturing (SIC 3) employment, 1000 persons. Source: CSO (Central Statistical Office), Bulletin of Statistics.

y = log of Finnish manufacturing output, millions of 1985 FIM. Source: CSO; Bulletin of Statistics.

w = log of wage costs. Average wage in manufacturing augmented with the payroll tax rate, index with 1985 = 100. Source: CSO (wage series) and Bank of Finland BOF4 (payroll tax rate series).

p = log of product price deflator, index with 1985 = 100. Source: CSO, Bulletin of Statistics.

m = log of the price of material costs in manufacturing, index with 1985 = 100. Source: CSO, Bulletin of Statistics.

c = net stock of fixed capital in manufacturing. Source: Bank of Finland BOF4.

i = the user cost of capital proxied by the real interest rate; pre- 1986 the base rate of the Bank of Finland, after 1986 the 3-month Helibor. Source: Bulletin, Bank of Finland.

DATA APPENDIX: Graphs of the data levels (X_t) and differences (ΔX_t)

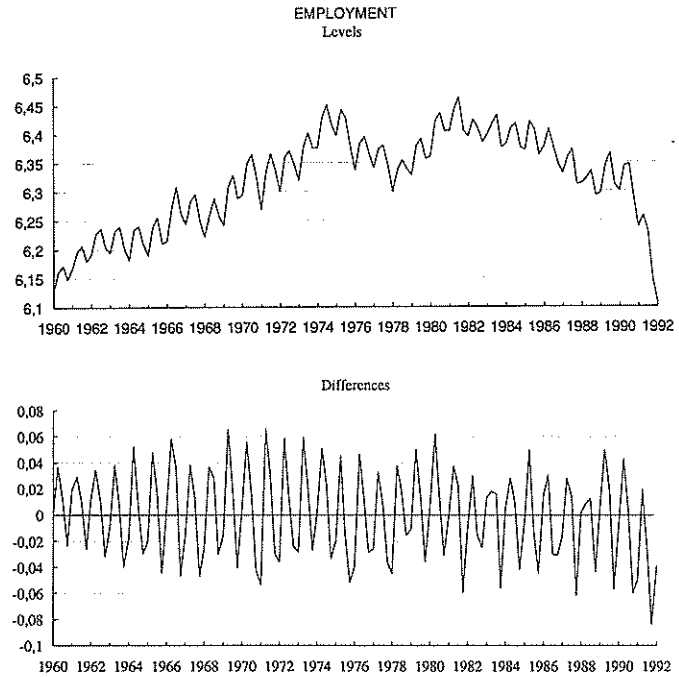

Figure 1.

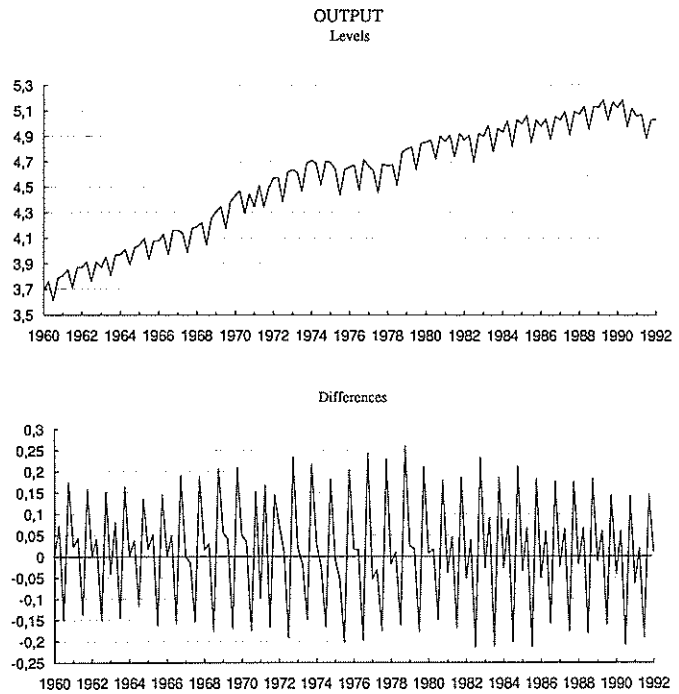

Figure 2.

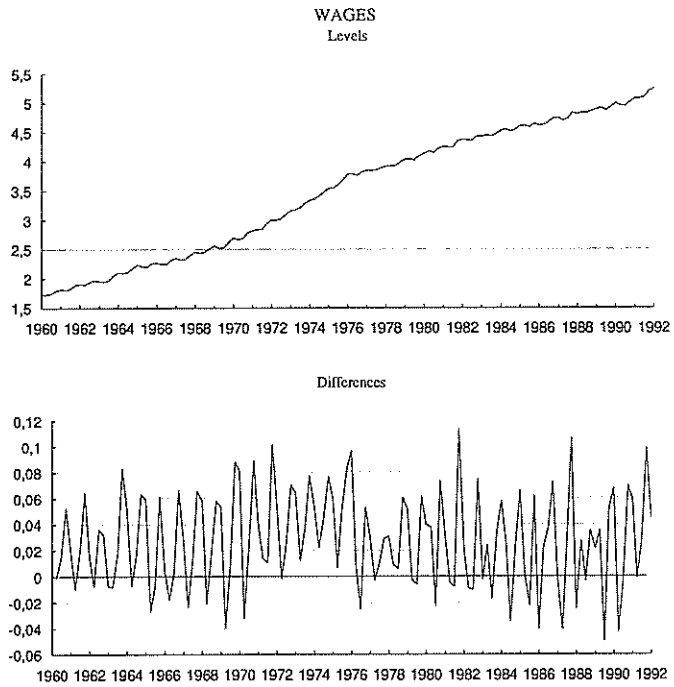

Figure 3.

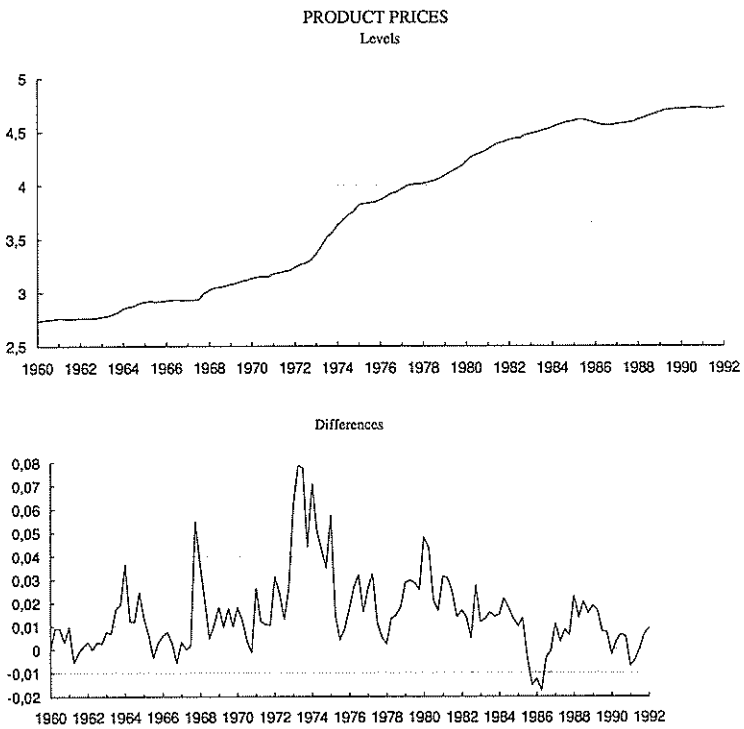

Figure 4.

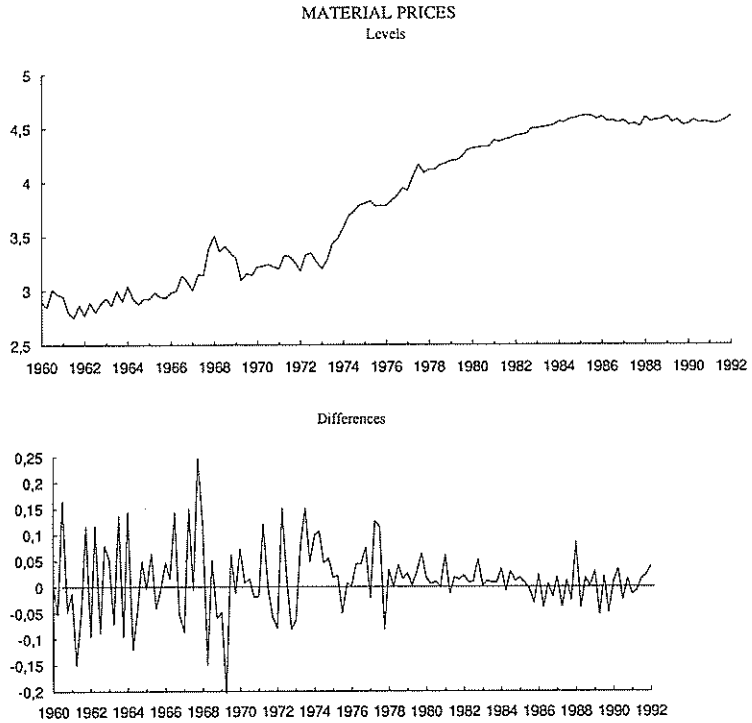

Figure 5.

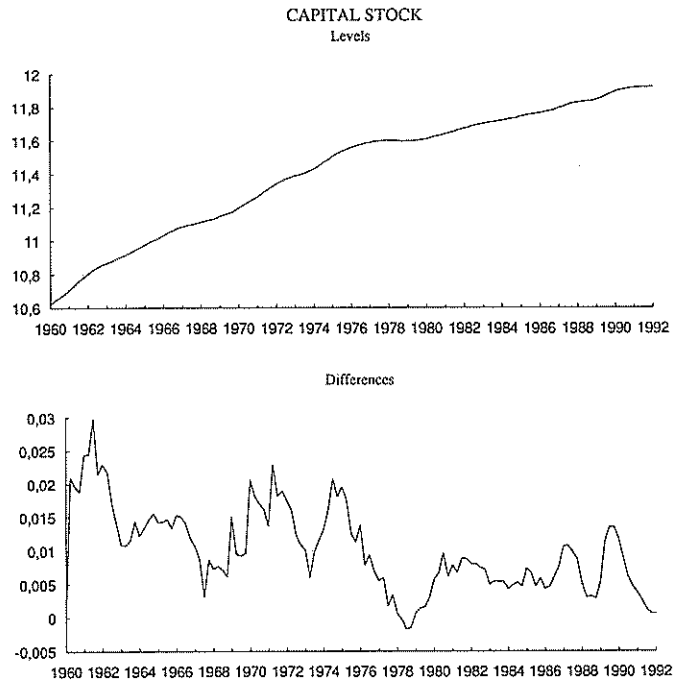

Figure 6.

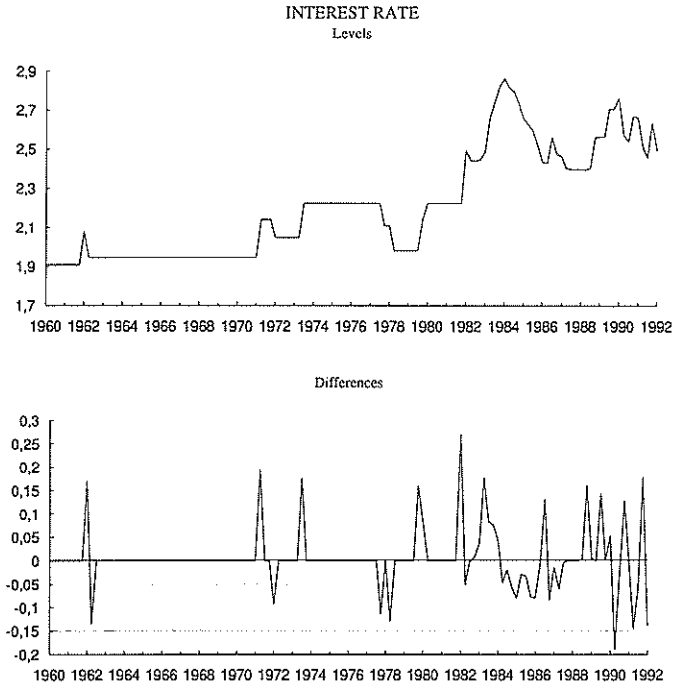
INTEREST RATE
Levels
2,9
2,7
2,5
2,3
2,1
1,9
1,7
1960 1962 1964 1966 1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992
Differences
0,3
0,25
0,2
0,15
0,1
0,05
0
-0,05
-0,1
-0,15
-0,2
1960 1962 1964 1966 1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992

Figure 7.