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WAGE FORMATION IN FINLAND IN THE 1980's; An Econometric Study

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ABSTRACT: The wage formation in the industrial sector has traditionally been modelled as a result of a bargaining game between the trade unions and the firms or the employers' organizations. In times of hectic economic activity, however, the wages tend to drift to considerably higher levels than agreed by the negotiating partners. In Finland, the wage drift has in some years even exceeded the simultaneous raises of the contract wages. This is why we have in our study split the wage increases into two parts: the raises of the contract wages on the one hand and the wage drift on the other. Because of the strong interdependence between wages and prices, we have actually built a three-equation econometric model with separate equations for the contract wages, for the wage drift, and for the inflation rate. The resulting model incorporates two error components, an annual one and a quarterly one. The annual error component is multiplied by an observable, exogenous allotment factor, which makes our model mathematically non-standard.

We derive a new, asymptotically efficient three-stage estimator for the structural parameters of the model. The estimator is computationally more feasible than the exact ML- estimator, but shares the same asymptotic properties.

Our empirical results show that the pace of the wage drift *is* affected by unanticipated inflation, but *not* by the corresponding forecast errors in the productivity. As predicted by our theoretical considerations, the wage heterogeneity and the balance on the labour market also seem to have significant effects on the drift.

KEY WORDS: Wage determination, simultaneous equation models, variance components.

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1. INTRODUCTION

1.1. Aims of the study

The primary purpose of this study is not to develop any new economic theory on wage formation in highly unionized countries, but simply to build an econometric model for the wage determination mechanism in Finland. The aim of the model is to depict the multilayered Finnish system of wage negotiations as truthfully as possible. Traditionally, the wages in the industrial sector have been studied as a whole by considering them as a result of game-like bargaining between the unions and the firms. Especially in countries with high level of unionization, it seems natural to try to apply ideas of contract theory in explaining the dynamics of the wage increases. The demands of the unions are usually based on some hopes for a desirable trajectory for the purchasing power of the workers. This is why the wage demands are certainly affected by the prevailing inflation expectations and by the income tax rates. The ability of the employers to pay higher wages, on the other hand, is certainly affected among other things by inflation, productivity and the profitability of the firms. The conditions on the labour market can also have an effect on the way that a compromise is reached between the conflicting interests of the negotiating partners.

In earlier studies, the average wage of an industrial worker has invariably been considered as one entity without dividing it into distinct components with different determination mechanisms. Still, at least in the Scandinavian system (see e.g. Holden, 1989) the wages consist of two clearly distinct components: In the collective bargaining, the employers and the unions agree only upon so-called contract wages, but most firms actually pay much more to some of their workers. The difference between the contract wages and the wages actually paid is usually called the wage drift. For a more detailed discussion of the Scandinavian system, see Holden (1989). For instance in Finland, the wage drift has amounted to nearly one half of the total wage increases in some years during the 1980's. In this article, we are trying to model the raises in the contract wages separately from the wage drift, because these two components are clearly influenced by quite different factors. This is the main novelty of our study in terms of economic theory. Although we are not going to say anything new about contract theory, we shall in fact present a theoretical explanation for the emergence of the wage drift.

The most important *econometric* novelty of this article is certainly the way we take into account the beginnings of new contract periods in our quarterly study. The required models turn out to be mathematically somewhat different from any models used so far. This is why we have had to develop some new estimation techniques for simultaneous models with error components.

Finally, it is quite clear that wages are simultaneously interdependent on consumer prices. This is why the wage formation cannot be adequately studied without taking this interdependence into account. There are of course other variables with a simultaneous link to wages as well, such as the unemployment rate etc., but the role of these other endogenous factors is not as dominating as is the role of inflation. This is why we are trying to model the wage - price relationship by a three-equation simultaneous econometric model, where the raises of the contract wages, the wage drift and the inflation rate are taken as endogenous variables. Within the framework of this model, we can then search for answers to many interesting questions, such as

- is the wage drift affected by the amounts of increases in the contract wages?
- are the negotiators of the central organizations able to anticipate the wage drift within the next contract period ?
- how large has the impact of the wage drift been on the inflation rate during the 1980's ?

In Sections 1.2. - 1.4. we shall briefly motivate the structure of the three equations in our model in terms of economic theory. The econometric implementation of the model will be explained in Section 2, and in Section 2.2. we shall discuss the problems involved in the acquisition of suitable data. After the statistical and methodological considerations in Section 3, we shall present our empirical results and the model diagnostics in Section 4. The conclusions will be compressed to a concise form in Section 5.

1.2. The determination of contract wages

In Finland, the contracts on the terms of work are formally made between the trade unions and the corresponding employers' organizations within each branch of the industry. The agreements have mostly been made for one year at a time. The starting date of a new period has usually been March 1. In most years, however, the essential contents of the contract has been already beforehand agreed upon in a collective bargaining between the Central Organization of the Trade Unions and the Employers' Confederation. Even in years when the central organizations have not been able to find a mutual agreement, the final contracts for different branches have been astonishingly alike in terms of wage increases. This is why we shall treat the whole industry as one branch and assume that the wage raises during the contract period are actually agreed upon between the central organizations.

In most years, there has been only two wage increases, but some kind of clause for the compensation of unanticipated inflation has usually been included in the contract as well. According to the clause, the workers will be compensated for the unanticipated part of the inflation, whenever it exceeds a given threshold before a given date. This explains why there has been even three raises of the contract wages in some years. Furthermore, two of the contracts in the 1980's have also included a clause guaranteeing compensation for the average wage drift even to branches where the drift would otherwise be nonexistent.

Because each agreement on the terms of work has been unique and both the amounts and the timings of the wage raises have varied, we have made use of the following strategy:
In the logical derivation of the model, our starting point has been the *total* amount of increase of the contract wages within the whole contract period. To distribute the total increase among the four quarters, we have constructed a kind of "allotment factor" variable to indicate the timings of the wage raises within each contract period. The allotment factor has been assigned values on the basis of the formal texts of the contracts. We shall treat this variable as exogenous, because there seems to be no way of predicting its values in advance. This research strategy can be further motivated by noting that the expectations held by the key economic research institutes in Finland on inflation, productivity, taxes, etc. that actually make up the information set accessible to the negotiators, are also formed on an *annual* basis. The most plausible models thus have to first explain, how the total *annual* increases of the contract wages are determined, and only then describe, how the timings of the raises are settled and how the total annual wage changes are allotted among the four quarters.

By thinking of all manufacturing industries as a kind of "large firm" and by concentrating on the total *annual* wage raises, we can actually use the so-called "right to manage"- model to describe the negotiations between the central organizations. For different versions of this well established model, see for instance Nickell and Andrews (1983) or Hoel and Nymoen (1988). Following the reasoning of Nickell and Andrews (1983), we shall assume that the employers' utility function depends on real profits, which in turn obey the model

$$\pi_t = p_t^e A_t^e f(L_t) - (1 + s_t^e) w_t L_t - C_t \tag{1.1}$$

where

p_t^e = expected ratio of the producer prices and the CPI
A_t^e = expected productivity
L_t = number of persons employed
w_t = real wages
s_t^e = average employment tax rate, expectation
C_t = fixed costs

and f denotes the aggregate production function.

The demand for labour $L_t^*(w_t)$ at a given level of real wages w_t can in principle be derived by maximizing (1.1) with respect to L_t . By assuming the fallback profits to be constant over time, we can take the value of the constant to be equal to 0.

On these premises, the employers' utility corresponding to real wages w_t would be of the form

$$U_t = U(\pi_t) \ ,$$

(1.2) $$\pi_t = p_t^e A_t^e f(L_t^*(w_t)) - (1+s_t^e)w_t L_t^*(w_t) - C_t$$

The trade unions are assumed to take care of a fixed pool of workers, and their joint utility function is supposed to be of the form

(1.3) $$u_t = \bar{u}_t + \{(1-\alpha)(1-\delta)L_{t-1} + \alpha L_t^*(w_t)\}(v_t - \bar{v}_t) \quad ,$$

where

$v_t = v(w_t(1-t_t) - \bar{w}_t)$,
$\bar{v}_t$ = utility of the unemployment benefits B_t
$\bar{u}_t$ = fall-back position, where all workers live on unemployment benefits
$\bar{w}_t$ = minimum real wage
t_t = average income tax rate .

See Nickell and Andrews (1983) for details. Parameter δ denotes the withdrawal rate and it is assumed to be constant. On the other hand, parameter α can depend on L_t in the sense that it is replaced by 1 whenever $L_t < (1-\delta)L_{t-1}$.

Suppose that the result of the negotiations is determined as an unsymmetric Nash solution of the bargaining problem, i.e. suppose that the agreed contract wages maximize the objective function

(1.4) $$[U_t(w_t)]^{\beta_t} [u_t(w_t) - \bar{u}_t]$$

with respect to w_t . The utilities $U_t(w_t)$ and $u_t(w_t)$ have been defined in (1.2) and (1.3) and β_t reflects the relative bargaining power of the trade unions.

Assume that there are no abrupt changes in the employment L_t . Following Nickell and Andrews (1983), we can then state that the nominal contract wages W_t^c will depend on the variables $P_t^e, \tilde{P}_t^e, 1+s_t^e, 1-t_t^e, A_t^e, ue_{t-1}$, B_t and β_t , approximately according to a log-linear model. Here ue_{t-1} means the unemployment rate at time $t-1$, P_t^e means the expected level of producer prices and $\tilde{P}_t^e$ the expected level of consumer prices. The inclusion of the unemployment rate ue_{t-1} can be motivated by noting that it should reflect the unemployment expectations fairly well and can thus serve as a proxy for the bargaining power of the unions β_t .

It is evident that if the nominal contract wages depend on the variables listed above according to a log- linear model, then the *changes* of the contract wages will follow a similar model, where the *changes* of the listed variables appear as explanatory variables.

In lack of suitable data, we have not tried to take the profitability of the firms or the proportion of long-term unemployment into account in our model.

1.3. The generation of the wage drift

Suppose that individual workers or small groups of workers can put forth wage claims of their own to their employer even after the contracts on the terms of work have been established. The workers can enhance their claims by threatening to leave the firm, if their wage demands are not met. This will lead to a kind of new, decentralized, often inexplicit wage bargaining, where both sides have an access to all the relevant information that the centralized agreement was based on. Furthermore, both sides are to some extent able to observe, how the prior expectations concerning inflation and productivity have come true. Although the different groups of workers may act on their own without knowing about each others demands, the employer of course has to take all the claims into account simultaneously and weigh them against each other in the framework of the profitability of the firm. For simplicity, we shall assume, that each group consists of only one worker, and that the same way of thinking can be applied to every employee, whether he actually makes any new wage claims or not. We shall use the same conceptual framework to determine an implicit "market value" even for those workers who are not making any claims.

We now define the profit function of a firm i employing m_i workers at the outset of period t. Let $L_{j,t}^{(i)}$ denote a 0/1- dummy indicating whether individual j stays with the firm for period t. Symbol $w_{j,t}^{(i)}$ denotes the wage of individual j in real terms, $w_{j,t}^{c}$ denotes the contract wage for his possible substitute and $c_{j,t}^{(i)}$ denotes the adjustment costs. The interpretations of the other variables are the same as before.

Whenever individual j decides to leave, the firm has two alternatives: either to manage without him or to replace him by another worker. The former alternative would lead to a production loss of the amount

$$F_{j,t}^{(i)} = f_i(L_{1,t}^{(i)},..,L_{j-1,t}^{(i)},1,L_{j+1,t}^{(i)},..,L_{m_i,t}^{(i)}) - f_i(L_{1,t}^{(i)},..,L_{j-1,t}^{(i)},0,L_{j+1,t}^{(i)},..,L_{m_i,t}^{(i)})$$

whereas the latter case would induce training costs $c_{j,t}^{(i)}$ to the firm. Assuming that the replacement probability $\kappa_{j,t}^{(i)}$ does not depend on the other variables involved, we can write the expected profits of firm i as

$$(1.5) \qquad \pi_{i,t} = p_{i,t}A_{i,t}f_i(L_{1,t}^{(i)},...,L_{m_i,t}^{(i)}) - (1+s_t)\sum_{j=1}^{m_i} w_{j,t}^{(i)}L_{j,t}^{(i)}$$

$$- \sum_{j=1}^{m_i} \kappa_{j,t}^{(i)}(1-L_{j,t}^{(i)})\left[(1+s_t)w_{j,t}^{c} + c_{j,t}^{(i)}\right] - \sum_{j=1}^{m_i}(1-\kappa_{j,t}^{(i)})(1-L_{j,t}^{(i)})p_{i,t}A_{i,t}F_{j,t}^{(i)} \quad .$$

The fall-back profits $\bar{\pi}_{i,t}^{(j)}$ can be derived by simply putting $L_{j,t}^{(i)}$ equal to zero:

$$\bar{\pi}_{i,t}^{(j)} = p_{i,t}A_{i,t}f_i(L_{1,t}^{(i)},..,L_{j-1,t}^{(i)},0,L_{j+1,t}^{(i)},..,L_{m_i,t}^{(i)}) - (1+s_t)\sum_{\nu=1,\nu\neq j}^{m_i} w_{\nu,t}^{(i)}L_{\nu,t}^{(i)}$$

$$-\sum_{\nu=1,\nu\neq j}^{m_i} \kappa_{\nu,t}^{(i)}(1-L_{\nu,t}^{(i)})\left[(1+s_t)w_{\nu,t}^c + c_{\nu,t}^{(i)}\right] - \sum_{\nu=1,\nu\neq j}^{m_i}(1-\kappa_{\nu,t}^{(i)})(1-L_{\nu,t}^{(i)})p_{i,t}A_{i,t}F_{\nu,t}^{(i)}$$

$$-\kappa_{j,t}^{(i)}\left[(1+s_t)w_{j,t}^c + c_{j,t}^{(i)}\right] - (1-\kappa_{j,t}^{(i)})p_{i,t}A_{i,t}F_{j,t}^{(i)} \quad .$$

The utility function is assumed to depend on the profits only,

$$U_{i,t} = U_i(\pi_{i,t}) \quad .$$

The fall-back utility for the "negotiations" with worker j thus becomes

$$\bar{U}_{i,t}^{(j)} = U_i(\bar{\pi}_{i,t}^{(j)}) \quad .$$

Note that if U_i is a linear function, all the other wages $w_{\nu,t}^{(i)}$ $(\nu \neq j)$ will cancel out from the difference $U_{i,t} - \bar{U}_{i,t}^{(j)}$.

The utility function of worker j is supposed to be of the form

$$u_{j,t}^{(i)} = u_{j,t}(w_{j,t}^{(i)}(1-t_t)) = v(w_{j,t}^{(i)}(1-t_t) - \bar{w}_t)$$

where the notations are analogous to formula (1.3). Note that the utility is assumed to be basically of the same form as in (1.3). This is quite natural, because we are now dealing with the same individuals that actually make up the trade unions.

The model we have in mind is remotely related to the so-called seniority model, c.f. Oswald (1985) or Carruth and Oswald (1989, Ch. 6).

We assume that the negotiations break down as soon as either side withdraws from the bargaining. According to the vocabulary of Binmore et al. (1986), we use an "outside option point" as the threat point by assuming that the worker would have to find another job whenever the negotiations break down. In such a case, the worker would even face the possibility of getting unemployed. This is contradictory to Holden (1989) and Holmlund and Skedinger (1990), who used the contract wage as the fall-back position for employees in the firm-level bargaining. In their concept, the Nash solution would always exceed the contract wage. Our assumption, however, allows the solution even to go below the contract wage, because the possibility of getting unemployed is always present. To avoid misunderstandings, we strongly underline, that our model is intended to describe a kind of implicit bargaining for the determination of a "market wage" for *every* single employee, irrespective whether he makes any explicit claims or not.

Finally, we assume that the "market wages" for different workers are settled one by one in some systematic order - e.g. in the order of seniority - and that our indexation follows that order with respect to j. This means that the market wage $w^*_{j,t}$ for individual j will be defined by maximizing the objective function

$$(U_{i,t} - \bar{U}^{(j)}_{i,t})^{\beta_{j,t}}(u^{(i)}_{j,t} - \bar{u}_{j,t})$$

with respect to $w^{(i)}_{j,t}$, where $\beta_{j,t}$ stands for the bargaining power of employee j and $\bar{u}_{j,t}$ for his fallback utility. Assume now that the employer already knows the wages of all workers prior to j, and that the employer gets prepared to increase the rest of the wages in accordance with the centralized agreement. These assumptions can be formalized by taking the $L^{(i)}_{\nu,t}$'s and $w^{(i)}_{\nu,t}$'s as observed for $\nu = 1,..,j-1$ and by putting tentatively $L^{(i)}_{\nu,t} = 1$ for $\nu \geq j$ and $w^{(i)}_{\nu,t} = w^{(i)}_{\nu,t-1} + (w^c_{\nu,t} - w^c_{\nu,t-1})$ for $\nu = j+1,...,m_i$. We can then see that our present optimization problem with respect to $w^{(i)}_{j,t}$ is exactly of the same mathematical form as the optimization of (1.4). This makes it rather obvious that the Nash solution $w^{*(i)}_{j,t}$ will depend on the other wages and on the variables $p_{i,t}$, $A_{i,t}$, $\tilde{P}_t$, $1+s_t$, $1-t_t$, $\beta_{j,t}$, $c^{(i)}_{j,t}, w^c_{j,t}$ and $\bar{u}_{j,t}$. As noted earlier, $w^{*(i)}_{j,t}$ will be independent of the other wages whenever the utility function U_i is linear.

At the next stage, we can solve the resulting system of equations for the wages $w^{*(i)}_{j,t}$ $(j = 1,...,m_i)$. We shall assume, that these reduced form equations can be approximated by log- linear models, analogous to the model for centralized bargaining in Section 1.2.

From now on, we shall denote the nominal wages by capital letters and drop the indexation referring to firms. Simultaneously, the single indexation referring to individuals will be extended to include *all* workers $j = 1,...,M$. For individual j, we define the ***pressure for wage drift*** as the ratio

(1.6) $$l^*_{j,t} = \frac{W^*_{j,t} - W^c_{j,t}}{W^c_{j,t}} = \frac{w^*_{j,t} - w^c_{j,t}}{w^c_{j,t}}$$

where $W^*_{j,t}$ stands for the "market wage" and $W^c_{j,t}$ for the contract wage in nominal terms. Note that $l^*_{j,t}$ can even attain negative values.

Assume that the pressure $l^*_{j,t}$ will be transformed into real wage drift only after exceeding a positive threshold $c_t > 0$. Putting it more formally, we assume that the *observed* nominal wage of individual j, $W_{j,t}$, will be determined as

(1.7) $$W_{j,t} = \begin{cases} (1+l^*_{j,t})W^c_{j,t} & \text{if} \quad l^*_{j,t} > c_t \\ W^c_{j,t} & \text{if} \quad l^*_{j,t} \leq c_t \end{cases}$$

The definition of the pressure (1.6) can be reformulated as

(1.8) $$\log(1 + l^*_{j,t}) = \log W^*_{j,t} - \log W^c_{j,t} \quad .$$

The logarithm of the actual wage will then be

$$\log\ W_{j,t} = \begin{cases} \log\ (1 + l^*_{j,t}) + \log\ W^c_{j,t} & \text{if} \quad l^*_{j,t} > c_t \\ \log\ W^c_{j,t} & \text{if} \quad l^*_{j,t} \le c_t \end{cases}$$

Suppose, that the distribution of $\log(1 + l^*_{j,t})$ over individuals j would be approximately normal. Denote the observed nominal wage of a randomly chosen individual by W_t , his contract wage by W^c_t and his pressure for drift by $l^*_t = \frac{W^*_t - W^c_t}{W^c_t}$. The normality assumption

$$\log\ (1 + l^*_t) \sim N(\mu_t, \sigma^2_t) \tag{1.9}$$

then implies that the expected logarithmic wage drift $E(D_t) = E(\log\ W_t - \log\ W^c_t)$ will be

$$E(D_t) \;=\; 0 \cdot P(l^*_t \le c_t) + E\left[\log\ (1 + l^*_t) \mid l^*_t > c_t\right]$$

$$= \int_{c^*_t}^{\infty} \frac{1}{\sqrt{2\pi}\sigma_t}\ s\ e^{-\frac{1}{2}\left(\frac{s-\mu_t}{\sigma_t}\right)^2}\ ds \quad \left[1 - \Phi\left(\frac{c^*_t - \mu_t}{\sigma_t}\right)\right]^{-1} \tag{1.10}$$

$$= \mu_t + \sigma_t \cdot \frac{\phi\left(\frac{c^*_t - \mu_t}{\sigma_t}\right)}{1 - \Phi\left(\frac{c^*_t - \mu_t}{\sigma_t}\right)}$$

where $c^*_t = \log\ (1 + c_t) > 0$, ϕ means the standard normal density function and Φ the corresponding cumulative distribution function. Note that the threshold c^*_t is assumed to increase simultaneously with μ_t . The probability $\Pi_t = 1 - \Phi(\frac{c^*_t - \mu_t}{\sigma_t})$ of an individual surpassing the threshold is assumed to change rather smoothly over time.

This means that the expected logarithmic wage drift $E(D_t)$ should be approximately linearly dependent on *both* parameters μ_t and σ_t in (1.9) . The corresponding result actually holds for most truncated distributions: The expectation of the truncated distribution is usually approximately linearly dependent on the standard deviation of the original distribution. The results of this paper should therefore not be too sensitive to deviations from the normality assumption (1.9) .

We can summarize our conclusions by saying that according to Nickell and Andrews (1983), $E(\log\ W^c_t)$ should depend linearly on $\log\ \tilde{P}^e_t$, $\log\ A^e_t$, on the union power, and on some other variables. Analogously, $E(\log\ W^*_t)$ should depend on $\log\ \tilde{P}_t$, $\log\ A_t$ and on the bargaining power of individual workers. We shall use the number of vacancies vac_t as an obvious proxy for the workers' bargaining power. Note, that the employers' adjustment costs $c^{(i)}_{j,t}$ in (1.5) also depend on the conditions on the labour market, and thus also on vac_t . The number of vacancies also affects the threat-points of the employees while determining the "market wages" for each individual. This is why vac_t actually affects the solution of the decentralized bargaining in three different ways.

As a consequence, the expectation of the logarithmic pressure for drift $\mu_t = E(\log W_t^*) - E(\log W_t^c)$ should be linearly dependent on $\log \bar{P}_t^e$, $\log \bar{P}_t$, $\log A_t^e$, $\log A_t$ and vac_t. According to (1.10), the expectation of the actual logarithmic drift $E(D_t)$ should then depend on at least the following variables:

(1.11) $\log \bar{P}_t^e$, $\log \bar{P}_t$, $\log A_t^e$, $\log A_t$, vac_t and σ_t .

1.4. Factors affecting the inflation rate

As far as the price equation of our model is concerned, we shall merely follow the lines of Branson and Myhrman (1976), Sargan (1980) and Saikkonen and Teräsvirta (1985) without penetrating any deeper into the theory of inflation. We adopt the "markup pricing" view on the pricing mechanism of Finnish products. According to the general understanding, the most important factors affecting the level of consumer prices $\bar{P}_t$ seem to be the following:

- domestic average wage level $\bar{W}_t$
- import prices I_t
- average rate of indirect taxes r_t
- productivity A_t

The import price level I_t of course has both direct and indirect effects on the domestic consumer prices $\bar{P}_t$. The prices of imported raw materials, unfinished products and investment goods affect the domestic producer prices and then eventually also the domestic consumer prices. This is why I_t - as well as $\bar{W}_t$ and A_t - might have both immediate and lagged effects on $\bar{P}_t$.
Because the contract wages and the wage drifts are both direct costs to the employers, we have no reason to make any distinction between these two components of $\bar{W}_t$ in our price equation.

2. FORMULATION OF THE ECONOMETRIC MODEL; ACQUISITION OF THE DATA

2.1. Modelling the contract wages

Statistics Finland is keeping up a quarterly index on the average level of contract wages $\bar{W}_t^c$ in Finland. The index is based on the information supplied by the Employers' Confederation. We shall make use of this index in our empirical study.

As already briefly explained in Section 1.2., the quarterly variation of this index includes at least three distinct components:

1° In the contracts on the terms of work, the negotiating partners agree upon the total amount of wage increases during the whole contract period, i.e. the whole year. The expectations that the partners have to base their decisions on, are also made on an annual basis. This is why we can use the theory of Nickell and Andrews (1983) only for modelling the *annual* variation of the contract wage index $\bar{W}_t^c$. According to the brief review of their article given in Section 1.2., we can use a simple log- linear regression model to describe the annual variation.

2° In addition to the total wage increases within each year, the negotiating partners also agree upon the timings of the wage raises. Since we have no theory to explain, how the timings are determined, and since they seem totally unpredictable, we shall simply have to multiply the total annual increase by an allotment factor in order to depict the quarterly variation of $\bar{W}_t^c$. The values of the allotment factor are non-negative and they sum up to 1 each year. The factor will be considered exogenous.

3° Part of the variation in $\bar{W}_t^c$ is due to miscellaneous reasons, such as changes in the structure of the work force, ambiguities in the technical recording of the contract wages, etc. This part of the variation will be modelled as random noise.

When all these three sources of variation are taken into account, the most plausible form of the model seems to be of the following type:

$$w_{ij}^c = (\gamma_{1o} + \gamma_{11}p_i^e + \gamma_{12}a_i^e + \gamma_{13}ue_i + \gamma_{14}wed_i + \xi_i)\cdot s_{ij} + \varepsilon_{ij}^{(1)} \tag{2.1}$$

where

$$i = \text{int}(\frac{t-1}{4}) + 1 \quad , \quad j = t - 4\cdot(i-1)$$

and t refers to time. The meanings of the symbols are as follows:

$w_{ij}^c =$ the logarithmic change of the contract wage index during quarter t, i.e. $\log \bar{W}_t^c - \log \bar{W}_{t-1}^c$

$p_i^e =$ the expected rate of inflation for the year i based on the information available at the end of the previous year

$a_i^e =$ the expected, logarithmic change of productivity for the year i

$ue_i =$ the annual change in the unemployment rate at the end of the year $i-1$

$wed_i =$ the annual logarithmic change of the wedge

$s_{ij} =$ the allotment factor that measures, how large a share of the total annual increase of the contract wages is allotted to quarter j in the year i ($s_{i1} + s_{i2} + s_{i3} + s_{i4} = 1$)

$\xi_i =$ the error term of the annual model

$\varepsilon_{ij}^{(1)} =$ the error term depicting the quarterly miscellaneous variation of w_{ij}^c

We shall make the following distributional assumptions concerning the error terms :

(2.2) $$\varepsilon_{ij}^{(1)} \sim NID(0, \sigma_1^2) \quad , \quad \xi_i \sim NID(0, \tau^2) \quad , \quad \{\xi_i\} \perp\!\!\!\perp \{\varepsilon_{ij}^{(1)}\} \; .$$

In comparing (2.1) to the theory presented in Chapter 1.2., it is to be noted that the expected average payroll tax variable $1 + s_i^e$ and the average income tax variable $1 - t_i$ have been merged into one entity, $WED_i = \frac{1+s_i^e}{1-t_i} \cdot$constant, which we shall call "wedge" for brevity. Of course, it will coincide with the actual wedge only, if the ratio between the producer prices and the consumer prices remains constant. For simplicity, we shall assume this to be the case. The variable wed_i appearing in the model (2.1) has been constructed as $wed_i = \log\ WED_i - \log\ WED_{i-1}$.

As proxies for the expectation variables p_i^e and a_i^e, we shall use the figures published in the most recent Economic Outlook of the Ministry of Finance. According to the interviews with several participants in the wage negotiations, both sides actually base their standpoints on the information supplied by the Finance Ministry.

The values of the allotment factor s_{ij} have been calculated for the years 1980-1988 on the basis of the texts of the wage agreements. The wage increases have mostly been defined in per cents. Whenever the pay raises have been agreed upon in nominal terms, we have converted them into per cent changes according to the official statistics on average hourly nominal wages. The per cent changes have been transformed onto a logarithmic scale, and all logarithmic changes within each year have been summed up. The quarterly logarithmic changes have then been divided by this annual sum, and the ratio has been assigned to s_{ij}. If the pay raises have been executed in the middle of a quarter, the values of s_{ij} have been calculated by linear interpolation. An exception to this rule is made only when the agreement has included a wage raise at March the 1st, but the agreement has been reached so late that the employers have not been able to make the actual payments simultaneously with March's salary. In these cases, the effects of the pay raise have been assigned almost totally to the second quarter.

One obvious drawback of the model (2.1)+(2.2) is that, like most difference models, it gives no guarantee that the *levels* of the wages would stay in proportion to the productivity. This is why we shall tentatively add an error correction term into the annual part of the model, namely

$$ec_i = \log\ \bar{W}_{i-1} - \log\ \bar{P}_{i-1} - \log\ A_{i-1} \quad . \tag{2.3}$$

The interpretations of the symbols have been explained above.

The enlarged model then becomes

$$w_{ij}^c = (\gamma_{1o} + \gamma_{11} p_i^e + \gamma_{12} a_i^e + \gamma_{13} ue_i + \gamma_{14} wed_i + \gamma_{15} ec_i + \xi_i) \cdot s_{ij} + \varepsilon_{ij}^{(1)} \quad , \tag{2.4}$$

$$\varepsilon_{ij}^{(1)} \sim NID(0, \sigma_1^2) \quad , \quad \xi_i \sim NID(0, \tau^2) \quad , \quad \{\xi_i\} \perp\!\!\!\perp \{\varepsilon_{ij}^{(1)}\} \quad ,$$

$$i = \text{int}(\frac{t-1}{4}) + 1 \quad , \quad j = t - 4\cdot(i-1) \quad .$$

2.2. Modelling the wage drift

We repeat our conclusion in Chapter 1.3. that the logarithmic expectation of the *cumulated* wage drift D_t should depend linearly on the variables listed in (1.11) .

The drift emerging at quarter t is then the difference

$$\nabla D_t = D_t - D_{t-1}$$

for a randomly chosen individual. The average value of ∇D_t can be approximated by

$$d_t = \nabla \left[\log \left(\frac{\bar{W}_t}{\bar{W}_t^c} \right) \right] = \log \left(\frac{\bar{W}_t \cdot \bar{W}_{t-1}^c}{\bar{W}_{t-1} \cdot \bar{W}_t^c} \right) = \nabla \log\ \bar{W}_t - \nabla \log\ \bar{W}_t^c \quad , \tag{2.5}$$

where $\bar{W}_t$ means the average industrial wage index for quarter t .

Note that

$$d_t \approx \frac{\bar{W}_t - \bar{W}_{t-1}}{\bar{W}_{t-1}} - \frac{\bar{W}_t^c - \bar{W}_{t-1}^c}{\bar{W}_{t-1}^c} \tag{2.6}$$

whenever the quarterly changes of the indices $\bar{W}_t$ and $\bar{W}_t^c$ remain small. Because the changes have never exceeded 5% in the 1980's, we can say that our definition of the wage drift at quarter t (2.5) very well conforms to the everyday meaning of the word (2.6) .

By merging the definition (2.5) and the result (1.11) we can conclude that d_t should depend linearly on the variables

$$\nabla \log \tilde{P}_t^e, \nabla \log \tilde{P}_t, \nabla \log A_t^e, \nabla \log A_t, \nabla vac_t \quad \text{and} \quad \nabla \sigma_t \quad .$$

All the other variables in the list are directly observable, but σ_t constitutes a problem. We shall simply use the standard deviation of the average hourly wages $stdw_t$, taken over branches, as a proxy for σ_t . We have divided the manufacturing industries into 8 branches, and the standard deviations of these 8 averages have been assigned as values for $stdw_t$.

One further problem that confounds the data is that the values of the average wage index $\bar{W}_t$ actually drop at the third quarter every year. This is due to the structural changes in the work force during the holiday season, when great numbers of low-paid substitutes temporarily join the work force. This makes it virtually impossible to give an estimate for the wage drift in the third quarter of each year.

To overcome this problem, we define a new operator ∇^* as follows:

$$\nabla^* D_t = \begin{cases} D_t - D_{t-1} & \text{if} \quad t \neq 4\cdot\text{int}(\frac{t-1}{4}) + 4 \\ D_t - D_{t-2} & \text{if} \quad t = 4\cdot\text{int}(\frac{t-1}{4}) + 4 \end{cases}$$

This means that the value of D_t in the fourth quarter of each year will not be compared to the corresponding value in the third quarter, but in the second quarter.
To allow for an exceptional level of $D_t - D_{t-1}$ in the third quarters, we shall formulate our final model simply as

(2.7) $$d_t^* = \nabla^* D_t = \beta_{21}\nabla^* \log \tilde{P}_t + \gamma_{20} + \gamma_{21}\delta_{3,t} + \gamma_{22}\nabla^* \log \tilde{P}_t^e$$
$$+\gamma_{23}\nabla^* \log A_t + \gamma_{24}\nabla^* \log A_t^e + \gamma_{25}\nabla^* vac_t + \gamma_{26}\nabla^* stdw_t + \varepsilon_t^{(2)}$$

where $\delta_{3,t}$ denotes a dummy for the third quarter, i.e. $\delta_{3,t} = 1$ if $t = 4\cdot\text{int}(\frac{t-1}{4}) + 3$, and zero otherwise.

The error term $\varepsilon_t^{(2)}$ is assumed to be normally distributed noise

(2.8) $$\varepsilon_t^{(2)} \sim NID(0, \sigma_2^2) \quad ,$$

but it may correlate simultaneously with $\varepsilon_t^{(1)}$ in (2.1).

This will be the largest model for d_t^* that we consider.

2.3. Modelling the inflation rate

As indicated earlier, we shall heavily rely on other people's experience in the specification of the price equation. The list of explanatory variables for the domestic price level was already given in Section 1.4. After some experimentation we found out that it sufficed to consider lagged effects of up to two quarters for the inflation rate and for the wage increases, whereas no lagged terms at all were necessary for the other explanatory variables. This is how we ended up with the following specification:

$$p_t = \gamma_{30} + \gamma_{31} i_t + \gamma_{32} p_{t-2} + \beta_{30} w_t + \gamma_{33} w_{t-1} + \gamma_{34} w_{t-2} + \gamma_{35} tax_t + \gamma_{36} a_{t-1} + \varepsilon_t^{(3)} \tag{2.9}$$

where

$p_t = \nabla \log \tilde{P}_t$ = the (logarithmic) inflation rate

$w_t = \nabla \log \bar{W}_t$ = the (logarithmic) wage increase at quarter t

$i_t = \nabla \log I_t$ = the rate of increase of the import prices

$tax_t = \nabla \log r_t$ = the (logarithmic) change in the rate of indirect taxes

$a_t = \nabla \log A_t$ = the annual (logarithmic) change in productivity

The error term $\varepsilon_t^{(3)}$ is assumed to be normally distributed noise

$$\varepsilon_t^{(3)} \sim NID(0, \sigma_3^2) \quad , \tag{2.10}$$

but it may correlate simultaneously with $\varepsilon_t^{(1)}$ and with $\varepsilon_t^{(2)}$.

To make the system of simultaneous equations (2.1), (2.7) and (2.9) complete, we note that by definition (2.5) , the values of the variable w_t in (2.9) can be constructed as

$$w_t = w_t^c + d_t^* - \delta_{3,t-1} d_{t-1}^*$$

where $w_t^c = \nabla \log \bar{W}_t^c = w_{ij}^c$ whenever $i = \text{int}(\frac{t-1}{4}) + 1$ and $j = t - 4\cdot(i-1)$.

To give a proper overview of the whole model (2.1) + (2.7) + (2.9) + (2.11), we have collected all the equations and a complete list of symbols into the Appendix A.

The technical novelty of this simultaneous equations model is that equation (2.1) contains error components with *observed* exogenous multipliers. This is why we shall have to briefly discuss the estimation methodology before proceeding to the more detailed analysis of our data.

3. SIMULTANEOUS EQUATION MODELS WITH ERROR COMPONENTS WITH OBSERVABLE MULTIPLIERS

The three-equations model $(2.4)+(2.7)+(2.9)$ derived in Section 2 can be taken as a special case of the following error components model:

$$Y_{ij} = \mathbf{B}\, Y_{ij} + \mathbf{\Gamma} X_{ij} + \psi_{ij} \tag{3.1}$$

where $E(\psi_{ij}) = 0 \quad , \quad \psi_{ij} = \xi_i S_{ij} + \varepsilon_{ij}$ and

$$\begin{cases} \{\xi_i\} \perp\!\!\!\perp \{\varepsilon_{ij}\}, \\ \xi_i \sim NID(0, \tau^2) \quad , \\ \varepsilon_{ij} = (\varepsilon_{ij}^{(1)} \quad . \quad . \quad . \quad \varepsilon_{ij}^{(K)})' \sim NID_K(0, \Sigma) \\ \text{for} \quad i = \text{int}(\frac{t-1}{k}) + 1 \quad , \quad j = t - k \cdot \text{int}(\frac{t-1}{k}) \end{cases}$$

The K- dimensional column vector Y_{ij} consists of the values of the endogenous variables, X_{ij} denotes the values of the M exogenous variables and S_{ij} consists of K known constants or values of exogenous variables that are completely independent of the error terms. The character t refers to time, k to the length of the seasonal period and $\text{int}(x)$ means the largest integer that is smaller or equal to x. In the application presented in Section 2, $K = 3, k = 4$ and n will refer to the number of years in the estimation period.

As far as we know, the estimation problems of models of the type (3.1) have never been studied before. Kelejian (1974) considered the identification problems in random parameters simultaneous equation models and found out that the identifiability of equations can be guaranteed with roughly similar conditions as in the constant parameter case. Estimation problems in simultaneous equation models with error components has been studied by Baltagi (1981), Magnus (1982), Hsiao (1986 , Ch. 5), Balestra and Varadharajan-Krishnakumar (1987) and others. None of these studies can, however, directly be applied to cases where one of the error components has been multiplied by an observable factor. On the other hand, the random coefficients models for panel data developed by Hsiao (1975), Kelejian and Stephan (1983) and others, do not allow for simultaneous dependencies between the dependent variables. This is why we shall first briefly discuss the estimation of parameters of models of the type (3.1).

The individual parameters will be denoted by the lower case letters whereas parameter vectors and matrices will be denoted by bold face capitals

$$\mathbf{B} = (\beta_{ij}) \quad \text{and} \quad \mathbf{\Gamma} = (\gamma_{ij}) \quad .$$

Further, denote

$$Y_i = \begin{pmatrix} Y'_{i1} \\ \vdots \\ Y'_{ik} \end{pmatrix} \quad , \quad X_i = \begin{pmatrix} X'_{i1} \\ \vdots \\ X'_{ik} \end{pmatrix} \quad ,$$

$$Y_i^* = \mathrm{vec}(Y_i)$$

and

$$Z_{i\nu} = (Y_i \quad X_i)\,\mathbf{C}_\nu$$

where $\mathbf{C}_\nu$ is a $(K+M) \times m_\nu$- matrix of zeros and ones extracting the variables that actually are included in the ν:th structural equation.
Correspondingly, denote by

$$\beta'_{(\nu)} = (\beta_{\nu 1} \quad \ldots \quad \beta_{\nu K} \quad \gamma_{\nu 1} \quad \ldots \quad \gamma_{\nu M})\,\mathbf{C}_\nu$$

the $m_\nu \times 1$- vector of structural parameters that actually appear in the ν:th equation.

By denoting $p = m_1 + \ldots. + m_K$,

$$S_i = \begin{pmatrix} S'_{i1} \\ \cdot \\ \cdot \\ \cdot \\ S'_{ik} \end{pmatrix} \quad , \qquad S_i^* = \mathrm{vec}(S_i) \quad ,$$

$$Z_i = \begin{pmatrix} Z_{i1} & \mathbf{0} & \ldots & \mathbf{0} \\ \mathbf{0} & Z_{i2} & \ldots & \mathbf{0} \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \mathbf{0} & \ldots & \mathbf{0} & Z_{iK} \end{pmatrix} \quad , \quad \beta = \begin{pmatrix} \beta_{(1)} \\ \cdot \\ \cdot \\ \beta_{(K)} \end{pmatrix} \in R^p \quad \text{and} \quad \varepsilon_i^* = \mathrm{vec}\left(\begin{pmatrix} \varepsilon'_{i1} \\ \cdot \\ \cdot \\ \varepsilon'_{ik} \end{pmatrix}\right)$$

we can reformulate model (3.1) in a more compact form

$$Y_i^* = Z_i\beta + \xi_i S_i^* + \varepsilon_i^* \tag{3.2}$$

where $\varepsilon_i^* \sim NID_{kK}(\mathbf{0}, \mathbf{\Sigma} \otimes \mathbf{I})$ and $\xi_i \sim NID(0, \tau^2)$, $\{\xi_i\} \perp\!\!\!\perp \{\varepsilon_i^*\}$.
The error term of the model (3.2) is of the special form

$$\psi_i^* = \xi_i S_i^* + \varepsilon_i^* \qquad i = 1, \ldots, n$$

and consequently

$$E(\psi_i^*) = 0 \qquad \text{and}$$
$$\mathrm{cov}(\psi_i^*) = \mathbf{\Sigma} \otimes \mathbf{I} + \tau^2 S_i^* S_i^{*\prime} \quad .$$

By the Sherman-Morrison-Woodbury formula (the matrix inversion lemma), the inverse of the covariance matrix can be written in the form

$$[\mathrm{cov}(\psi_i^*)]^{-1} = (\mathbf{\Sigma} \otimes \mathbf{I})^{-1} - (\mathbf{\Sigma} \otimes \mathbf{I})^{-1} \tau S_i^* \left[\mathbf{I} + \tau^2 S_i^{*\prime} (\mathbf{\Sigma} \otimes \mathbf{I})^{-1} S_i^*\right]^{-1} \tau S_i^{*\prime} (\mathbf{\Sigma} \otimes \mathbf{I})^{-1} \quad . \tag{3.3}$$

The Jacobian determinant of the transformation $\varepsilon_{ij} \longrightarrow Y_{ij}$ is equal to $[\det(\mathbf{I} - \mathbf{B})]^{-1}$ and, consequently, the log- likelihood will be of the form

$$l(\beta, \tau, \Sigma) = \sum_{i=1}^{n} \log L_{Y_i|X_i,S_i}(\mathrm{B}, \Gamma, \tau^2, \Sigma)$$

$$= nk \log |\det(\mathbf{I} - \mathrm{B})| - \frac{nk}{2} \log(\det\Sigma) - \frac{1}{2}\sum_{i=1}^{n} \log(1 + \tau^2 S_i^{*\prime}(\Sigma \otimes \mathbf{I})^{-1} S_i^{*})$$

$$(3.4) \qquad -\frac{1}{2}\sum_{i=1}^{n}\{E_i'(\Sigma \otimes \mathbf{I})^{-1}E_i - \frac{\tau^2}{1+\tau^2 S_i^{*\prime}(\Sigma\otimes\mathbf{I})^{-1}S_i^{*}}[S_i^{*\prime}(\Sigma\otimes\mathbf{I})^{-1}E_i]^2\},$$

where $E_i = Y_i^{*} - Z_i\beta$. Because of the regularity of the likelihood, (3.4) could in principle be straightforwardly maximized with respect to the parameters by any efficient general optimization algorithm, such as the DFP-, GM- or BHHH- algorithm. In practice, however, extremely good starting values are needed to ensure convergence, because the number of parameters is very large. According to our experience, the exact ML- estimation technique is actually quite impracticable in this case. Furthermore, the maximum of (3.4) can sometimes be attained with $\tau^2 < 0$, i.e. outside the parameter space. We do not discuss this possibility any further, because $\hat{\tau}^2 < 0$ can be taken as rather strong evidence against the fitted model, and the estimation results are thus more or less irrelevant. The problem does not differ in any way from the corresponding problem of negative variance estimates in ordinary error components models.

Because the straightforward maximization of (3.4) is prohibitively tedious, we are going to suggest a simpler, asymptotically efficient method for the estimation of β and Σ when $\tau^2 > 0$ is assumed fixed. This method can then be combined to a grid search for τ^2.
Assuming $\tau^2 \geq 0$ to be fixed, we can realize that in technical terms, (3.4) very much resembles the likelihood function of an ordinary simultaneous equations model. Because $E\psi_{ij} = 0$, we can estimate $\mathbf{B}$ and $\mathbf{\Gamma}$ consistently by the usual 2SLS- estimators $\tilde{\mathbf{B}}$ and $\tilde{\mathbf{\Gamma}}$. Denote the corresponding residuals by

$$\tilde{\psi}_{ij} = Y_{ij} - \tilde{\mathbf{B}}Y_{ij} - \tilde{\mathbf{\Gamma}}X_{ij}$$

and estimate $\mathbf{\Sigma}$ by

$$(3.5) \qquad \tilde{\mathbf{\Sigma}} = \frac{1}{nk}\{\sum_{i=1}^{n}\sum_{j=1}^{k}\tilde{\psi}_{ij}\tilde{\psi}_{ij}' - \tau^2\sum_{i=1}^{n}\sum_{j=1}^{k}S_{ij}S_{ij}'\} \quad .$$

This estimator makes use of the fact that we assumed $\{\xi_i\}$ and $\{\varepsilon_{ij}\}$ to be mutually independent. The consistency of $\tilde{\mathbf{\Sigma}}$ follows directly from the consistency of $\tilde{\mathbf{B}}$ and $\tilde{\mathbf{\Gamma}}$.

In the next step, compute the upper triangular Cholesky- decomposition of $\tilde{\mathbf{\Sigma}}$,

$$\tilde{\mathbf{\Sigma}} = \mathbf{U}\mathbf{U}'$$

and note that

$$(\tilde{\Sigma} \otimes \mathbf{I})^{-1} = (\tilde{\Sigma}^{-1} \otimes \mathbf{I}) = (\mathbf{U}^{-1} \otimes \mathbf{I})' \; (\mathbf{U}^{-1} \otimes \mathbf{I})$$

where $\mathbf{U}^{-1}$ is an upper triangular matrix as well.

Ignoring for a moment the term $nk \log \mid \det(\mathbf{I} - \mathbf{B}) \mid$ in (3.4), the maximization of the likelihood $\sum_{i=1}^{n} \log L_{Y_i|X_i,S_i}(\mathbf{B}, \mathbf{\Gamma}, \tau^2, \tilde{\Sigma})$ with respect to $\mathbf{B}$ and $\mathbf{\Gamma}$ would now be equivalent to minimizing the quadratic form

$$(3.6) \qquad Q(\beta) = \sum_{i=1}^{n} \{E_i'(\tilde{\Sigma} \otimes \mathbf{I})^{-1} E_i - \frac{\tau^2}{1 + \tau^2 S_i^{*\prime}(\tilde{\Sigma} \otimes \mathbf{I})^{-1} S_i^*} \left[S_i^{*\prime}(\tilde{\Sigma} \otimes \mathbf{I})^{-1} E_i\right]^2\} \; ,$$

where $E_i = Y_i^* - Z_i \beta$.
By defining the following $(kK + 1) \times 1$- vectors

$$S_i^{**} = \begin{pmatrix} 1 \\ \tau(\mathbf{U}^{-1} \otimes \mathbf{I}) S_i^* \end{pmatrix} \;, \quad Y_i^{**} = \begin{pmatrix} 0 \\ \tau(\mathbf{U}^{-1} \otimes \mathbf{I}) Y_i^* \end{pmatrix} \;, \quad E_i^{**} = \begin{pmatrix} 0 \\ \tau(\mathbf{U}^{-1} \otimes \mathbf{I}) E_i \end{pmatrix}$$

and the $(kK + 1) \times p$ matrix

$$Z_i^{**} = \begin{pmatrix} 0 \\ \tau(\mathbf{U}^{-1} \otimes \mathbf{I}) Z_i \end{pmatrix} \;,$$

the quadratic form (3.6) can be written as

$$(3.6') \qquad Q(\beta) = \sum_{i=1}^{n} E_i^{**\prime}(\mathbf{I} - \mathcal{P}_{S_i^{**}}) E_i^{**}$$

where

$$\mathcal{P}_{S_i^{**}} = S_i^{**}(S_i^{**\prime} S_i^{**})^{-1} S_i^{**\prime} \quad .$$

Because the dominating part of (3.4) can be formulated as a sum of squared errors (3.6′), it is obvious that (3.4) can be efficiently maximized with respect to β by the Newton-Raphson algorithm without any danger of indefinite Hessians.
Denote

$$Y^{**} = \begin{pmatrix} Y_1^{**} \\ \cdot \\ \cdot \\ Y_n^{**} \end{pmatrix} \;, \quad S^{**} = \begin{pmatrix} S_1^{**} & 0 & \cdot & \cdot & \cdot & 0 \\ 0 & S_2^{**} & \cdot & \cdot & \cdot & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ 0 & \cdot & \cdot & \cdot & 0 & S_n^{**} \end{pmatrix} \;, \quad Z^{**} = \begin{pmatrix} Z_1^{**} \\ \cdot \\ \cdot \\ Z_n^{**} \end{pmatrix} \;.$$

Note that Y^{**} is an $n(kK + 1) \times 1$- vector, S^{**} is an $n(kK + 1) \times n$- matrix and Z^{**} is an $n(kK + 1) \times p$- matrix, where $p = m_1 + \ldots + m_K$.

Denote further

$$X^{**} = (Z^{**} \quad S^{**}) \qquad \text{and} \qquad \beta^{**} = \begin{pmatrix} \beta \\ \beta^* \end{pmatrix} \;,$$

where β^* is an $n \times 1$ vector of regression coefficients for the rows of S^{**}. With this notation, it is obvious that

$$\min_{\beta} Q(\beta) = \min_{\beta^{**}} (Y^{**} - X^{**}\beta^{**})'(Y^{**} - X^{**}\beta^{**}) \quad .$$

In addition to $Q(\beta)$, $nk \log \mid \det(\mathbf{I} - \mathbf{B}) \mid$ is the only term in (3.4) that still depends on the β- parameters. Because $g(\beta^{**}) = nk \log \mid \det(\mathbf{I} - \mathbf{B}) \mid$ does not depend on β^* or $\mathbf{\Gamma}$, the majority of the entries in the gradient vector $Dg(\beta^{**})'$ and in the Hessian matrix $D^2 g(\beta^{**})$ will actually be zero.

Formula (3.6)′ implies that the maximization of (3.4) with respect to $\mathbf{B}$ and $\mathbf{\Gamma}$ will be equivalent to minimizing

$$(Y^{**} - X^{**}\beta^{**})'(Y^{**} - X^{**}\beta^{**}) - 2g(\beta^{**}) \tag{3.7}$$

with respect to β^{**} . The Newton-Raphson algorithm minimizing (3.7) will consist of the following steps

$$\beta^{**}_{(j)} = \{X^{**\prime}X^{**} - D^2 g(\beta^{**}_{(j-1)})\}^{-1}\{X^{**\prime}Y^{**} - D^2 g(\beta^{**}_{(j-1)})\beta^{**}_{(j-1)} + Dg(\beta^{**}_{(j-1)})'\} \tag{3.8}$$

$$j = 1, 2, \ldots .$$

Starting from the obvious initial value

$$\beta^{**}_{(o)} = (X^{**\prime}X^{**})^{-1}X^{**\prime}Y^{**}$$

this algorithm will converge *very* quickly. For a fixed $\tau^2 \geq 0$ we thus have

$$\hat{\beta}_\tau = (\mathbf{I} \quad \mathbf{0}) \lim_{j \to \infty} \beta^{**}_{(j)} \tag{3.9}$$

as our estimator for β . The corresponding value of (3.4)

$$l_{\max}(\tau) = l(\hat{\beta}_\tau, \tau, \tilde{\Sigma}) = \sum_{i=1}^{n} \log L_{\mathbf{Y}_{.i}|\mathbf{X}_{.i}\mathbf{S}_{.i}}(\hat{\mathbf{B}}_\tau, \hat{\mathbf{\Gamma}}_\tau, \tau^2, \tilde{\Sigma})$$

can then be calculated.

At the final stage we find the maximum of $l_{\max}(\tau^2)$ by a grid search, and denote the maximizing value by $\hat{\tau}_{3S}$. Our final three-stage ($3S$) estimator for β will then be

$$\hat{\beta}_{3S} = \hat{\beta}_{\hat{\tau}_{3S}} \quad . \tag{3.10}$$

Proposition 1: *If no structural restrictions are imposed on* Σ *in the model* (3.1) *, then* $\hat{\beta}_\tau$ *in* (3.9) *will be an asymptotically efficient estimator for* β *for each fixed* $\tau \geq 0$.

Proof: Assume τ to be fixed. Because the 2SLS- estimators $\tilde{\mathbf{B}}$ and $\tilde{\Gamma}$ are consistent for $\mathbf{B}$ and Γ, the estimator $\tilde{\Sigma}$ for Σ will share the same property whenever no restrictions are imposed on the elements of Σ. From (3.4) it is easy to see that for a fixed τ^2, the information matrix

$$-ED^2 l_\tau(\boldsymbol{\beta}, \boldsymbol{\Sigma}) = -ED^2 \sum_{i=1}^{n} \log L_{Y_i|X_i,S_i}(\mathbf{B}, \boldsymbol{\Gamma}, \tau^2, \boldsymbol{\Sigma})$$

will be block diagonal. This is because

(3.11)
$$\frac{d}{d\boldsymbol{\beta}} l_\tau(\boldsymbol{\beta}, \boldsymbol{\Sigma}) = \frac{d}{d\boldsymbol{\beta}} nk \log |\det(\mathbf{I} - \mathbf{B})|$$
$$-\sum_{i=1}^{n} Z_i' \{(\boldsymbol{\Sigma} \otimes \mathbf{I})^{-1} E_i - \frac{\tau^2}{1 + \tau^2 S_i^{*\prime} (\boldsymbol{\Sigma} \otimes \mathbf{I})^{-1} S_i^*} (\boldsymbol{\Sigma} \otimes \mathbf{I})^{-1} S_i^* S_i^{*\prime} (\boldsymbol{\Sigma} \otimes \mathbf{I})^{-1} E_i\},$$

and consequently

$$-E \frac{d^2}{d\boldsymbol{\beta} d\boldsymbol{\Sigma}} l_\tau(\boldsymbol{\beta}, \boldsymbol{\Sigma})$$
$$= \sum_{i=1}^{n} \left[\frac{d}{d\boldsymbol{\Sigma}} Z_i' \{(\boldsymbol{\Sigma} \otimes \mathbf{I})^{-1} - \frac{\tau^2}{1 + \tau^2 S_i^{*\prime} (\boldsymbol{\Sigma} \otimes \mathbf{I})^{-1} S_i^*} (\boldsymbol{\Sigma} \otimes \mathbf{I})^{-1} S_i^* S_i^{*\prime} (\boldsymbol{\Sigma} \otimes \mathbf{I})^{-1}\} \right] E\, \boldsymbol{E}_i$$
$$= 0$$

Thus, for *any* consistent estimator $\tilde{\Sigma}$, the maximizing value of $l_\tau(\beta, \tilde{\Sigma})$ will be asymptotically efficient for β.

Proposition 2: ***With the assumptions of Proposition 1,*** $\hat{\tau}_{3S}$ ***in*** (3.10) ***will be consistent for*** τ.

Proof: Because of the consistency of $\tilde{\Sigma}$, Proposition 1 directly implies

$$\operatorname{p}\lim_{n \to \infty} \frac{1}{n} l_\tau(\hat{\beta}_\tau, \tilde{\Sigma}) = \operatorname{p}\lim_{n \to \infty} \frac{1}{n} l(\beta, \tau, \Sigma),$$

which in turn implies the consistency of $\hat{\tau}_{3S}$.

Proposition 3: *With the previous assumptions,* $\hat{\beta}_{3S}$ *will be an asymptotically efficient estimator for* β.

Proof: Just as in the proof of Proposition 1, we only have to show that the information matrix is block diagonal with respect to β and τ^2. It follows from (3.11) that

$$-E\frac{d^2}{d\beta d\tau}l(\beta,\tau,\Sigma)$$
$$=\sum_{i=1}^{n}\left[\frac{d}{d\tau}Z_i'\{(\Sigma\otimes\mathbf{I})^{-1}-\frac{\tau^2}{1+\tau^2S_i^{*\prime}(\Sigma\otimes\mathbf{I})^{-1}S_i^*}(\Sigma\otimes\mathbf{I})^{-1}S_i^*S_i^{*\prime}(\Sigma\otimes\mathbf{I})^{-1}\}\right]E\ E_i$$
$$=0$$

Because $\hat{\tau}_{3S}$ and $\hat{\Sigma}$ are both consistent, the proposition has thus been proved.

4. EMPIRICAL RESULTS

4.1. Specification of the model

To start with, we estimated the combined model $(2.1) + (2.7) + (2.9)$ exactly in the form indicated in Section 2 with data covering the time span 1980 - 1988. It soon turned out, however, that in the wage drift equation (2.7), the estimated coefficients of $\nabla^* \log \tilde{P}_t^e$, $\nabla^* \log A_t$ and $\nabla^* \log A_t^e$ were not significant and of the wrong signs, whereas the *observed* inflation rate $\nabla^* \log \tilde{P}_t$ seemed to have a clear, positive impact on the drift. This is why we dropped out the variables $\nabla^* \log \tilde{P}_t^e$, $\nabla^* \log A_t$ and $\nabla^* \log A_t^e$ from the equation. Similarly, the variables tax_t and a_{t-1} were temporarily dropped out of equation (2.9), because both of them seemed to lack explanatory power. The simplified joined model thus became

$$
(4.1)\quad \begin{cases}
w_{ij}^c = (\gamma_{1o} + \gamma_{11} p_i^e + \gamma_{12} a_i^e + \gamma_{13} ue_i + \gamma_{14} wed_i + \xi_i)\cdot s_{ij} + \varepsilon_{ij}^{(1)} \\
d_t^* = \nabla^* D_t = \beta_{21} \nabla^* \log \tilde{P}_t + \gamma_{20} + \gamma_{21}\delta_{3,t} + \gamma_{25}\nabla^* vac_t + \gamma_{26}\nabla^* stdw_t + \varepsilon_t^{(2)} \\
p_t = \gamma_{30} + \gamma_{31} i_t + \gamma_{32} p_{t-2} + \beta_{30} w_t + \gamma_{33} w_{t-1} + \gamma_{34} w_{t-2} + \varepsilon_t^{(3)} \\
\xi_i \sim NID(0, \tau^2) \quad , \quad \{\xi_i\} \perp\!\!\!\perp \{(\varepsilon_{ij}^{(1)} \;\; \varepsilon_t^{(2)} \;\; \varepsilon_t^{(3)})'\} \\
(\varepsilon_{ij}^{(1)} \;\; \varepsilon_t^{(2)} \;\; \varepsilon_t^{(3)})' \sim NID_3(0, \Sigma) \qquad \text{where} \\
\Sigma = \begin{pmatrix} \sigma_1^2 & \sigma_{12} & \sigma_{13} \\ \sigma_{12} & \sigma_2^2 & \sigma_{23} \\ \sigma_{13} & \sigma_{23} & \sigma_3^2 \end{pmatrix} \quad \text{and} \quad i = \text{int}(\tfrac{t-1}{4}) + 1 \quad , \quad j = t - 4\cdot(i-1)
\end{cases}
$$

The estimation results of model (4.1) have been reported in Table 1 under the heading Model I. The first thing we wanted to test was whether the inclusion of the annual error term in model (2.1) was really necessary or not. By estimating the same model with $\tau = 0$ we got $l(\hat{\beta}_0, 0, \tilde{\Sigma}) = -47.95$ as the log- likelihood. The LR- test statistic testing $H_o: \; \tau = 0$ is thus $-2\cdot(45.43 - 47.95) = 5.03$ corresponding to a p- value $p = 0.025$. Note also that the estimated $\hat{\tau} = 0.0051$ is larger than $\tilde{\sigma}_1 = 0.0035$ indicating that the annual error component actually dominates the variation of the combined error term in (2.1). The same dominance seemed to prevail in all other models that we estimated. This is why we do not report the LR- test statistics for the hypothesis $H_o: \; \tau = 0$ anew after every small change of the model.

The estimates of the coefficients in Model I seem quite sensible except that the t- value of the unemployment variable is very low. This is why we changed the definition of the variable ue_i to mean the annual change in the average unemployment during the months November, December and January. The resulting estimates have been reported in Table 1 under the heading Model II. Although the new definition of the ue_i- variable only shifts the span of the moving average one month later, the change had rather dramatic effects on the estimated coefficients. In our view, the new results seem much more plausible than the old ones. In addition to this, the estimated standard deviations of the error components $\hat{\tau}$ and $\tilde{\sigma}_1$ decreased slightly. This is why we decided to adopt the latter version of the unemployment variable.

Table 1:

Estimation results for different versions
of the model (2.1)+ (2.7)+ (2.9)

			Model I		Model II	
EQUATION	Variable	Parameter	Estimate	(t- value)	Estimate	(t- value)
Eq. I: Contract wages	constant	γ_{10}	-0.0518	(-1.48)	-0.0866	(-2.98)
	p_i^e	γ_{11}	0.857	(3.63)	1.003	(5.57)
	a_i^e	γ_{12}	1.648	(2.38)	2.504	(4.06)
	ue_i	γ_{13}	-0.00645	(-0.464)	-0.0305	(-2.96)
	wed_i	γ_{14}	-0.627	(-1.80)	-1.214	(-3.85)
	Annual disturbance	τ	0.0051		0.0043	
	Quarterly disturbance	σ_1	0.0035		0.00297	
Eq. II: Wage	constant	γ_{20}	0.0105	(12.86)	0.0105	(12.64)
	$\delta_{3,t}$	γ_{21}	-0.0156	(-7.15)	-0.0156	(-7.00)
	$\nabla^* \log \tilde{P}_t$	β_{21}	0.101	(3.41)	0.101	(3.35)
	$\nabla^* vac_t$	γ_{25}	0.00000281	(3.12)	0.00000284	(3.11)
	$\nabla^* stdw_t$	γ_{26}	0.00156	(3.75)	0.00155	(3.67)
	Disturbance	σ_2	0.0027		0.0027	
Eq. III: Inflation rate	constant	γ_{30}	-0.00458	(-1.03)	-0.00424	(-0.937)
	i_t	γ_{31}	0.169	(3.05)	0.174	(3.10)
	p_{t-2}	γ_{32}	-0.716	(-10.79)	-0.722	(-10.72)
	w_t	β_{30}	0.497	(7.12)	0.498	(7.03)
	w_{t-1}	γ_{33}	0.498	(5.34)	0.489	(5.18)
	w_{t-2}	γ_{34}	0.527	(7.33)	0.522	(7.16)
	Disturbance	σ_3	0.0064		0.0064	
	Log- likelihood		-45.43		-45.92	

Table 2:

Estimation results for different versions of the model (2.4)+ (2.7)+ (2.9)

EQUATION	Variable	Parameter	Model III Estimate	Model III (t- value)	Model IV Estimate	Model IV (t- value)
Eq. I: Contract wages	constant	γ_{10}	-0.072	(-2.06)	0.682	(0.62)
	p_i^e	γ_{11}	1.001	(5.60)	0.525	(0.77)
	a_i^e	γ_{12}	2.493	(4.17)	2.360	(3.78)
	ue_i	γ_{13}	-0.0309	(-3.09)	-0.0231	(-1.62)
	wed_i	γ_{14}	-1.227	(-4.03)	-0.707	(-0.92)
	[$\nabla_4 D_i$]	[γ_{16}]	[-0.428]	[(-0.60)]		
	ec_i	γ_{15}			0.172	(0.70)
	Annual disturbance	τ	0.0036		0.0035	
	Quarterly disturbance	σ_1	0.0031		0.0031	
Eq. II: Wage drift	constant	γ_{20}	0.0107	(12.68)	0.0106	(12.75)
	$\delta_{3,t}$	γ_{21}	-0.0127	(-6.64)	-0.0129	(-6.78)
	$\nabla^* \log \tilde{P}_t$	β_{21}	0.0850	(2.79)	0.0891	(2.95)
	[$\nabla^* \log \bar{W}_t^c$]	[β_{22}]	[0.0617]	[(0.668)]		
	[$\nabla^* \log \bar{W}_{t-1}^c$]	[γ_{23}]	[-0.087]	[(-1.48)]		
	$\nabla^* vac_t$	γ_{25}	0.00000273	(2.91)	0.00000285	(3.07)
	$\nabla^* stdw_t$	γ_{26}	0.00169	(3.96)	0.00162	(3.83)
	[$(t-28)\cdot\nabla^* stdw_t$]	[γ_{27}]	[-0.000093]	[(-1.53)]		
	Disturbance	σ_2	0.0027		0.0027	
Eq. III: Inflation rate	constant	γ_{30}	0.00034	(0.61)	0.00044	(0.08)
	i_t	γ_{31}	0.193	(3.29)	0.189	(3.22)
	p_{t-2}	γ_{32}	-0.690	(-8.30)	-0.687	(-8.24)
	w_t	β_{30}	0.428	(5.21)	0.426	(5.17)
	w_{t-1}	γ_{33}	0.510	(4.63)	0.514	(4.65)
	w_{t-2}	γ_{34}	0.457	(4.83)	0.454	(4.79)
	tax_t	γ_{35}	0.311	(0.78)	0.320	(0.80)
	a_{t-1}	γ_{36}	-0.058	(-1.32)	-0.0596	(-1.36)
	Disturbance	σ_3	0.0063		0.0063	
	Log- likelihood		-43.85		-43.68	

The most apparent thing in the first equation of Model II is that the estimated coefficients of p_t^e and wed_t are almost exactly equal to 1 and -1, respectively. This conforms well to our prior expectations, because the tax rates have invariably been set well before the decisive stages of the wage negotiations. The wedge variable wed_t is thus a part of the information set that is accessible to the negotiators. On the other hand, the estimated coefficient for the productivity expectations a_t^e is rather far above 1 compared to the standard deviation of the estimate, 0.617.

In the wage drift equation, the explanatory power of the wage heterogeneity $\nabla^* stdw_t$ and of $\nabla^* vac_t$ seem rather good. This fact lends some support to our theory on the emergence of the wage drift developed in Section 1.3.

At the next stage we tried to include the indirect tax variable tax_t and the lagged productivity variable a_{t-1} to the price equation again. The results have been shown in Table 2 under the heading Model III. Simultaneously, we tentatively included several other additional variables to the two wage equations. The estimation results connected to the role of these additional variables have been shown in Table 2 in square brackets.

It turned out that the changes in the average rate of indirect taxes tax_t and the lagged changes in productivity a_{t-1} lacked explanatory power within this model specification too. Because these variables should logically be incorporated in the price equation and because the estimates were of the right signs, we actually accepted these variables to our maintained model anyway.

The total annual drift $\nabla_4 D_t$ was tentatively included in the contract wage equation to test, whether the negotiators seem to anticipate the wage drift during the negotiations or not. The result of the test was negative in the sense that $\nabla_4 D_t$ seemed to be totally superfluous, but the negative constant term of the first equation might of course be interpreted as a kind of reservation for future wage drift.

On the other hand, we also wanted to test, whether large raises of the contract wages have any restraining effects on the wage drift. To this aim, we included the variables $\nabla^* \log \bar{W}_t^c$ and $\nabla^* \log \bar{W}_{t-1}^c$ to the second equation of the model. The concurrent variable $\nabla^* \log \bar{W}_t^c$ had of course to be handled as endogenous. No instantaneous interdependence between the variables $\nabla^* \log \bar{W}_t^c$ and $\nabla^* D_t$ could be found. On the other hand, the lagged variable $\nabla^* \log \bar{W}_{t-1}^c$ might have some weak negative effects on the drift $\nabla^* D_t$. This finding seems quite plausible, because the wages are not likely to drift much right after a steep raise in the contract wages.

One more thing we wanted to test was whether the proportion of workers, who actually benefit from the drift, stays invariant or not. As explained in Section 1.3., we assumed this proportion $\Pi_t = 1 - \Phi(\frac{c_t^i - \mu_t}{\sigma_t})$ to stay constant over time. The constancy of Π_t is obviously equivalent to the constancy of the coefficient of σ_t in the wage drift model. Because we had to substitute a proxy for σ_t in equation II, we cannot unfortunately derive the value of Π_t from the value of $\hat{\gamma}_{26}$. What we can do instead, is to test the constancy assumption against some specific alternative, such as a linear trend in the coefficient of $\nabla^* stdw_t$. To this end, we calculated the t- value of the variable $(t-28)\cdot\nabla^* stdw_t$, after it had been tentatively included in Model III. According to the results presented in Table II, there seems to be no obvious trend in γ_{26}. We can thus say, that the observed data are not contradictory to the assumption of Π_t staying constant.

Because the results of Model III raised some doubts that the increases of the contract wages might have been excessive in comparison to the improvements in the productivity, we next tried to augment the first equation by an error correction term ec_i as defined in (2.3). This augmentation did not seem to improve the fit of the model at all. On the contrary, it distorted the estimation results of the first equation rather badly. This is because the error correction variable ec_i seemed to have a monotone trend, whereas no corresponding trend could be found in the previous residuals of the first equation. According to our data, the trend reflects the fact that the productivity has actually grown even faster than the contract wages. As an explanation for the rather large estimate of γ_{12} we can mention that the *expected* improvements in the productivity published by the Ministry of Finance have always been far smaller than the actual final figures. Consequently, we refrained from any further attempts to incorporate an error correction mechanism into the model and accepted version III as our maintained model.

It is of course interesting to see, how much and how fast the wage drift affects the domestic inflation rate p_t. Assume that an exogenous shock Δ would have been added to the wage drift d_t^* at time $t = t_o$. The corresponding estimates for the impulse responses $\omega_o, \omega_1, \omega_2, \ldots$ in the inflation rate p_t would then be

$$\hat{\omega}_o = 0.444 \qquad \hat{\omega}_1 = 0.550 \qquad \hat{\omega}_2 = 0.199$$
$$\hat{\omega}_3 = -0.363 \qquad \hat{\omega}_4 = -0.118$$

for the first year. In order to draw any conclusions about the longer term effects of this exogenous shock, we would of course have to make some further assumptions concerning the expectation formation mechanism that generates the inflation expectations p_t^e. Anyway, we can formally estimate the total response by summing up the impulse response estimates

$$\sum_{i=0}^{\infty} \hat{\omega}_i = (\hat{\beta}_{30} + \hat{\gamma}_{33} + \hat{\gamma}_{34})\cdot(1 - \hat{\beta}_{30}\hat{\beta}_{21} - \hat{\gamma}_{32} - \hat{\gamma}_{34}\hat{\beta}_{21} - \hat{\gamma}_{33}\hat{\beta}_{21})^{-1} = 0.890 \quad .$$

These calculations reveal that the effects of exogenous shocks in the wage drift tend to carry over to domestic prices very quickly indeed. The firms seem to seek full compensation for the additional costs caused by the drifting wages through raising the domestic prices correspondingly within six months time.

4.2. Model diagnostics

The goodness of fit of Model III has been visualized in Figures 1-3, where the actual and the fitted values of w_{ij}^c, d_t^* and p_t have been demonstrated. The corresponding R^2- measures are 0.929 for the first equation, 0.864 for the second and 0.942 for the third. In the first equation, the fitted values were calculated simply as

$$\hat{w}_{ij}^c = (\hat{\gamma}_{1o} + \hat{\gamma}_{11}p_i^e + \hat{\gamma}_{12}a_i^e + \hat{\gamma}_{13}ue_i + \hat{\gamma}_{14}wed_i)\cdot s_{ij}$$

This means that the residual sum of squares actually comprises both the annual and the quarterly error variations.

Perhaps the most relevant assumptions in the model (4.1) concern the behaviour of the disturbances, namely

$$\begin{cases} \varepsilon_t = \left(\varepsilon_{ij}^{(1)} \quad \varepsilon_t^{(2)} \quad \varepsilon_t^{(3)}\right)' \sim NID_3(0,\Sigma) \qquad \text{where} \\ i = \text{int}(\frac{t-1}{4}) + 1 \qquad , \qquad j = t - 4\cdot(i-1) \end{cases}$$

It is fairly straightforward to test the serial independence of ε_t by means of the residuals by estimating their cross-correlations or by stepwise VAR- fits as suggested in Tiao and Box (1981). To obtain estimates for the quarterly disturbances $\varepsilon_{ij}^{(1)}$ in the contract wage equation, we first calculated

$$\tilde{e}_{ij}^{(1)} = w_{ij}^c - \hat{w}_{ij}^c$$

and estimated the parameters α_i $(i = 1, ..., n)$ by least squares from the equation

$$\tilde{e}_{ij}^{(1)} = \alpha_i \ s_{ij} + \tilde{\varepsilon}_{ij}^{(i)} \tag{4.2}$$

where the s_{ij}'s denote the values of the allotment factor variable. The corresponding OLS- residuals $e_{ij}^{(1)} = \tilde{e}_{ij}^{(1)} - \hat{\alpha}_i \ s_{ij}$ were then used as estimates for $\varepsilon_{ij}^{(1)}$ $(i = 1, ..., n \ ; \ j = 1, ..., k)$.

The cross correlation matrices of the residual series $e_t = \left(e_t^{(1)} \ e_t^{(2)} \ e_t^{(3)}\right)'$ for lags 1−5 have been displayed in Table 3. The residuals were calculated from Model III with the variables $\nabla_4 D_i$, $\nabla^* \log \bar{W}_t^c$ and $\nabla^* \log \bar{W}_{t-1}^c$ excluded. Significant values (values outside the range $\pm\ 2\cdot\frac{1}{\sqrt{kn}}$) have been denoted by asterisks. There is only one cross correlation that slightly exceeds the significance limit, namely $\text{corr}(e_t^{(1)}, e_{t+1}^{(2)}) = -0.36$. Quite obviously, this correlation only confirms the previous finding that there might be a weak negative association between $\nabla^* \log \bar{W}_{t-1}^c$ and d_t^*. All the higher order cross correlations from lag 6 on were very small indeed.

In addition to this cross correlation, Table 3 reveals some weak autocorrelation in the residual series $e_t^{(2)}$ at lags 2 and 4. Anyway, these autocorrelations are so small that it would hardly be worth while to complicate the model any further in order to take this serial dependence into account. Such a weak correlation should not affect the estimates of the structural parameters too much.

The autocorrelation functions of the individual series $e_t^{(1)}$, $e_t^{(2)}$ and $e_t^{(3)}$ have been displayed in Figures 4 - 6. The corresponding Box-Ljung test statistics for the five first autocorrelations were B-L = 8.9 ($p = 0.113$) for the first equation, B-L = 14.8 ($p = 0.011$) for the second equation and B-L = 7.8 ($p = 0.168$) for the third equation.

Furthermore, we tentatively fitted VAR- models of increasing orders to the residual vectors e_t in order to test, whether any significant serial dependencies could be found in the e_t- series. The LR- test statistics (see Tiao and Box, 1981) and the corresponding p- values have been listed in Table 4. No need for augmenting the model (4.1) with a VAR error structure seemed to arise.

The normality assumption of ε_t was tested by applying the Shapiro-Wilk test separately to $e_t^{(1)}$, $e_t^{(2)}$ and to $e_t^{(3)}$. The resulting test statistics were S-W = 0.951 ($p = 0.182$) for $e_t^{(1)}$, S-W = 0.976 ($p = 0.733$) for $e_t^{(2)}$ and S-W = 0.945 ($p = 0.129$) for $e_t^{(3)}$. The corresponding cumulative probit plots seemed very linear thus confirming the results of the normality tests.

The homoskedasticity of the error terms were tested against the alternatives that the error variances would be somehow associated either to time or to the level of the corresponding fitted values. We used the test suggested by Breusch and Pagan (1979). The test statistics attained the values B-P = 0.217 ($p = 0.897$) for the first equation, B-P = 0.074 ($p = 0.964$) for the second equation and B-P = 0.673 ($p = 0.714$) for the third equation.

With the exception of the weak autocorrelation in the series $e_t^{(2)}$, all assumptions concerning the behaviour of the disturbances in the model (4.1) seemed thus quite realistic.

Figure 1

Quarterly changes of contract wages

Observed (solid line) and fitted values

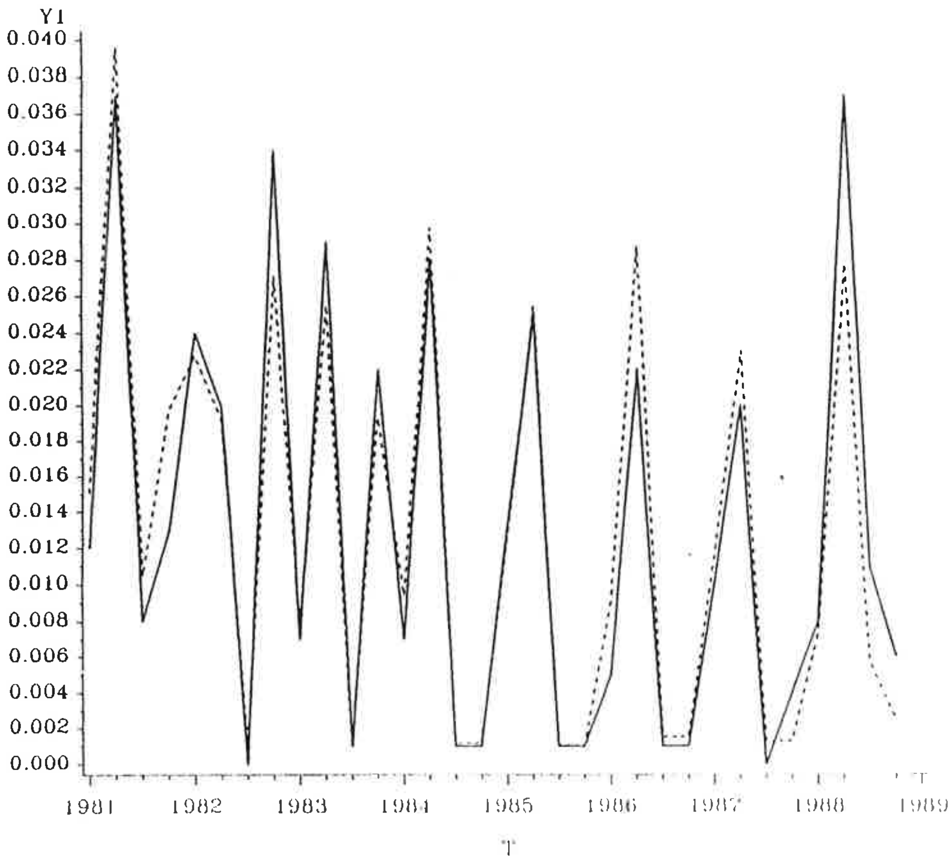

Figure 2

Quarterly wage drift

Observed (solid line) and fitted values

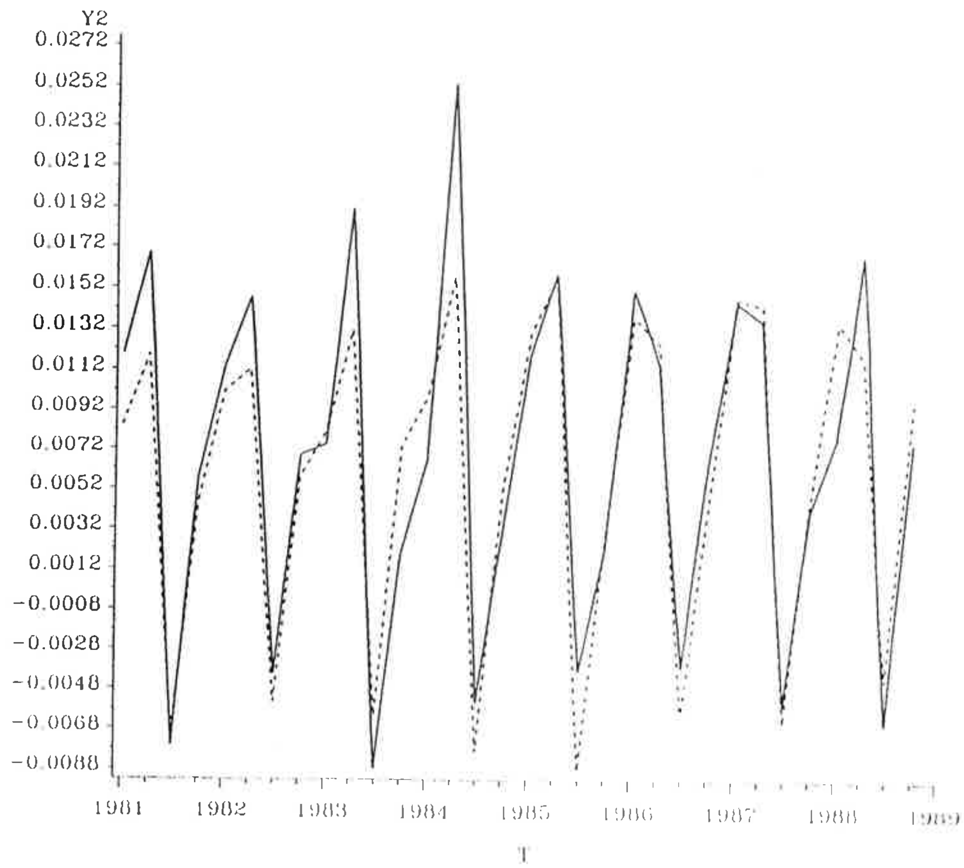

Figure 3

Quarterly inflation rate
Observed (solid line) and fitted values

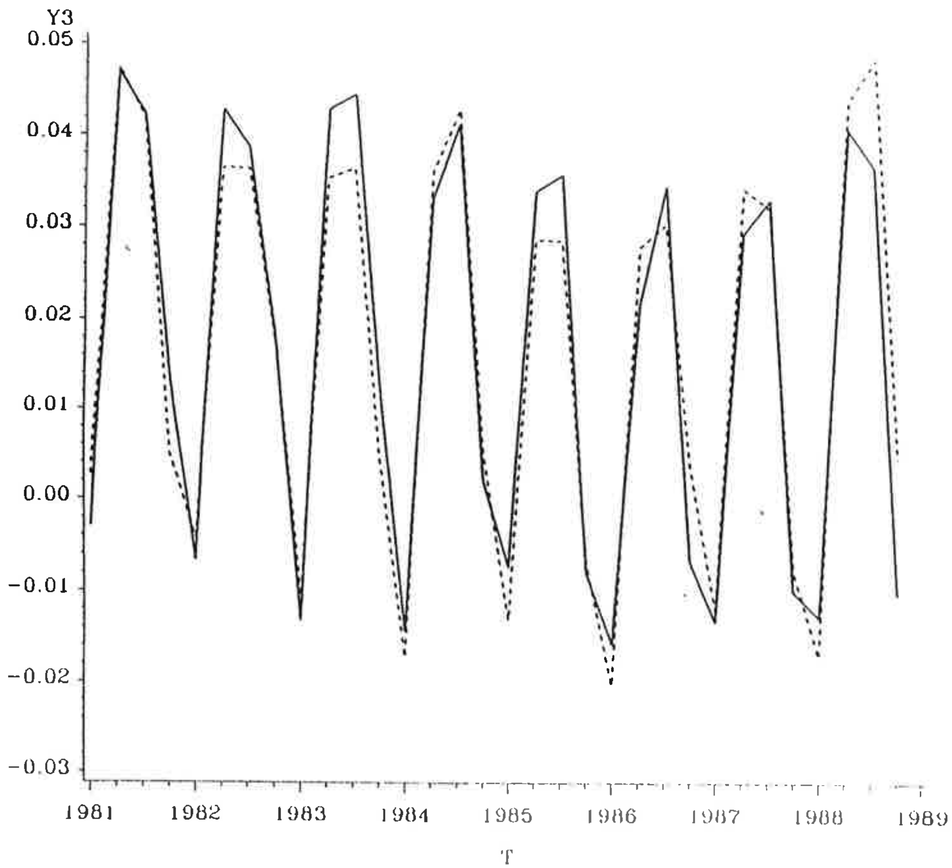

Figure 4

Residual autocorrelation in equation I

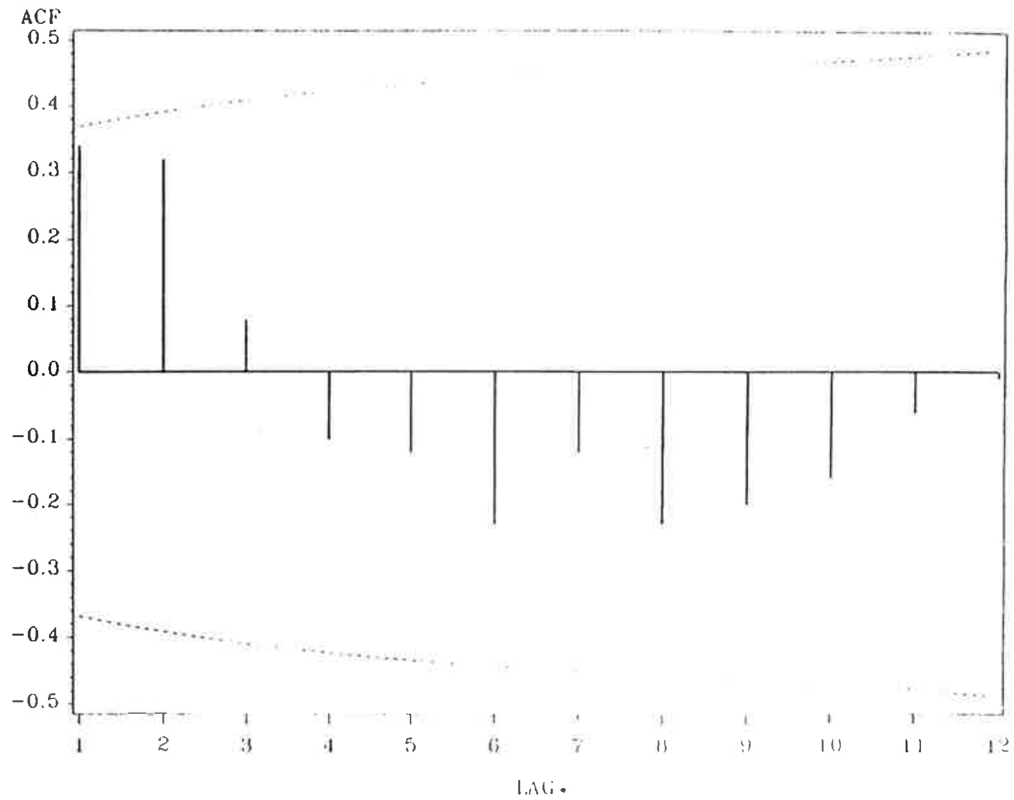

Figure 5

Residual autocorrelation in equation II

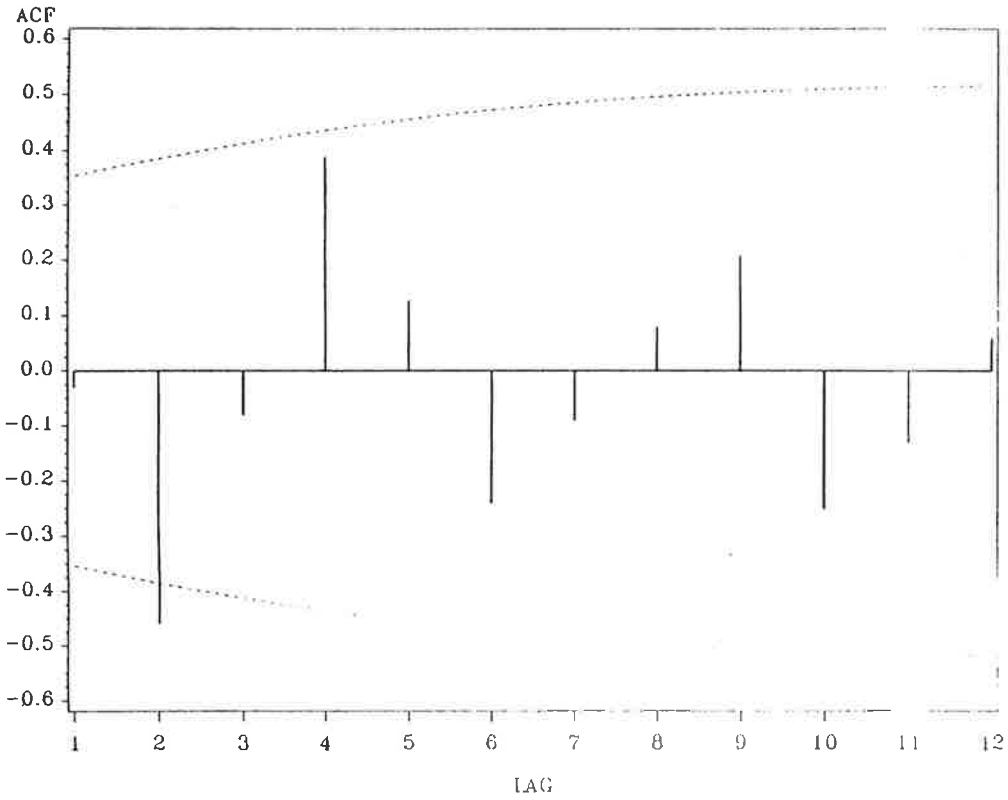

Figure 6

Residual autocorrelation in equation III

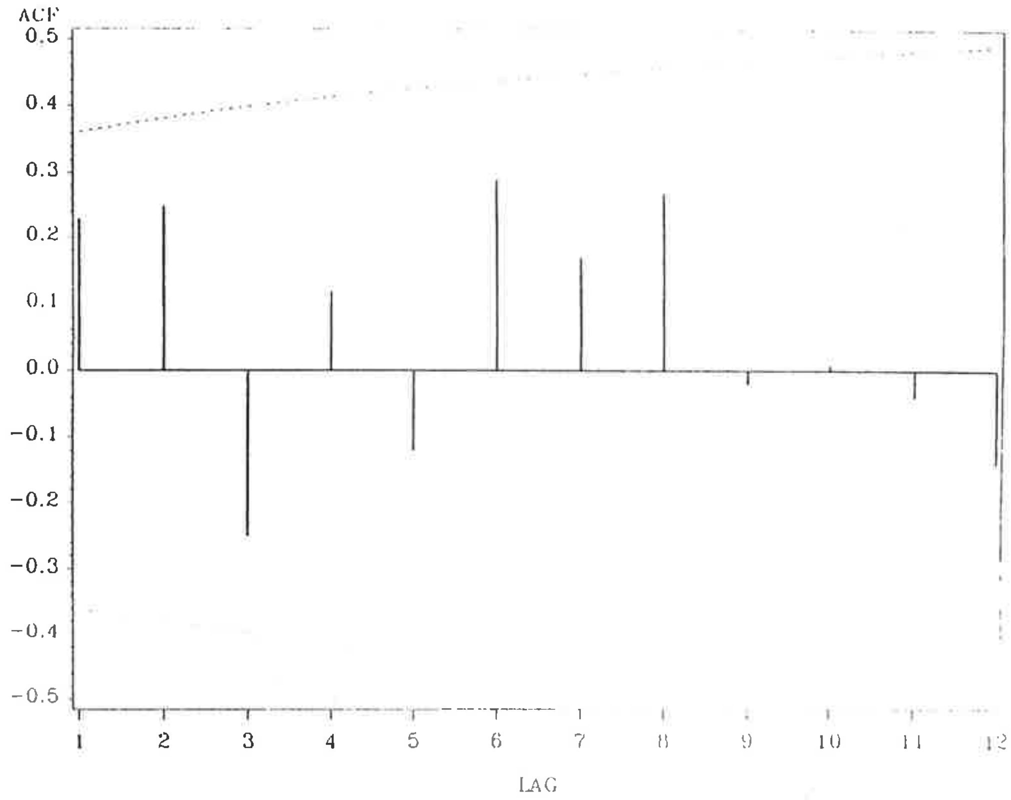

Figure 7

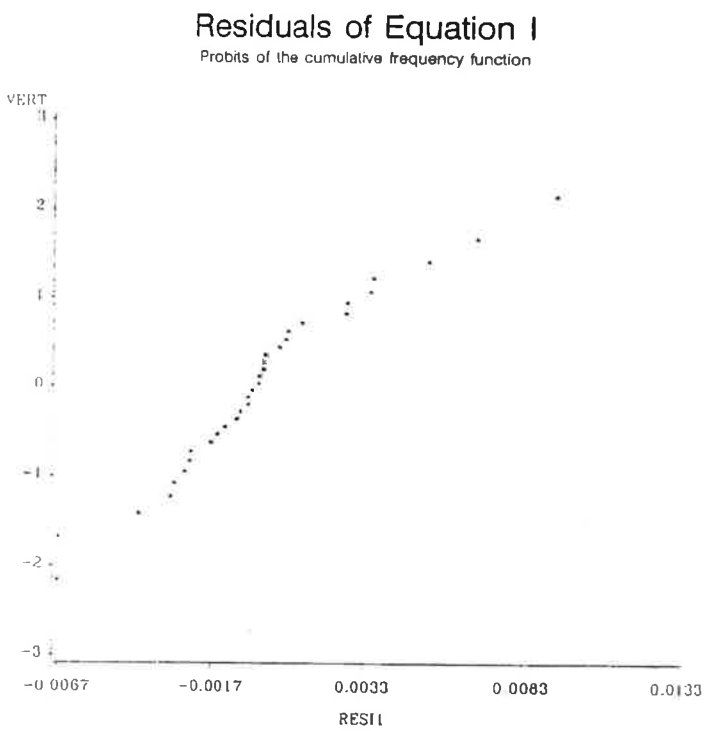

Figure 8

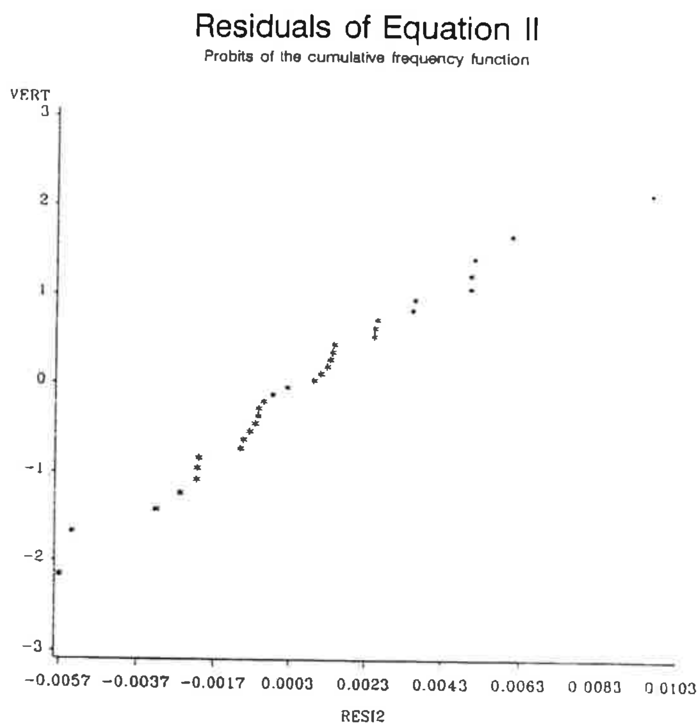

Figure 9

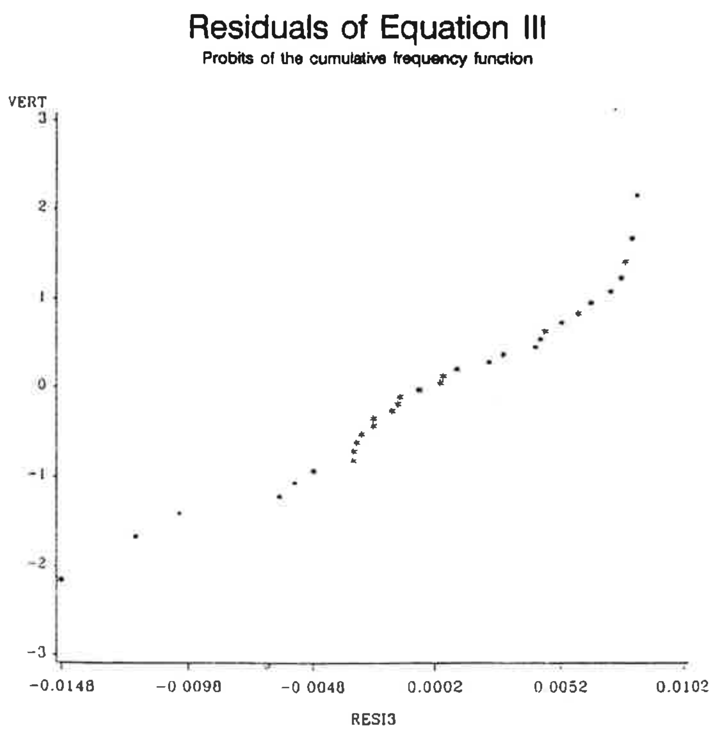

Table 3:

Cross correlation matrices of the residuals

		$e_t^{(1)}$	$e_t^{(2)}$	$e_t^{(3)}$
Lag 1	$e_{t+1}^{(1)}$	0.34	-0.08	0.00
	$e_{t+1}^{(2)}$	-0.36*	-0.03	-0.05
	$e_{t+1}^{(3)}$	-0.23	-0.19	0.23
Lag 2	$e_{t+2}^{(1)}$	0.32	-0.14	0.07
	$e_{t+2}^{(2)}$	-0.02	-0.46*	0.10
	$e_{t+2}^{(3)}$	-0.12	0.19	0.25
Lag 3	$e_{t+3}^{(1)}$	0.08	-0.22	-0.13
	$e_{t+3}^{(2)}$	-0.03	-0.08	0.10
	$e_{t+3}^{(3)}$	-0.01	0.23	-0.25
Lag 4	$e_{t+4}^{(1)}$	-0.10	0.02	-0.10
	$e_{t+4}^{(2)}$	-0.03	0.39*	0.22
	$e_{t+4}^{(3)}$	0.01	0.25	0.12
Lag 5	$e_{t+5}^{(1)}$	-0.12	0.09	-0.11
	$e_{t+5}^{(2)}$	-0.08	0.13	-0.12
	$e_{t+5}^{(3)}$	0.12	-0.02	-0.12

Table 4:

VAR- fits of increasing orders to the residual series $\left(e_t^{(1)} \quad e_t^{(2)} \quad e_t^{(3)}\right)'$

Lag	LR-test statistic	AIC	p- value
1	12.11	-32.93	0.21
2	15.67	-33.17	0.074
3	13.91	-33.46	0.13
4	7.13	-33.42	0.62
5	10.15	-33.83	0.34

4.3. Updating the data set

Because the figures for the years 1989 and 1990 are presently available, we of course wanted to test, how well the estimated model is able to predict these most recent observations. However, every economist with an interest in Finnish affairs knows that these were exceptional times, when the recent deregulation of the money market and the simultaneous rapid growth of production led to severe overheating symptoms in the economy. On the other hand, the Eastern European export market for Finnish products almost vanished during the years 1990 and 1991, which in conjunction to other factors led to an unprecedentedly sharp decline in the economic activity in 1991 and 1992. In addition to these unexpected developments, the predictive use of model (4.1) was rendered even more difficult by some technical and legislative changes in the recording of the data. For instance, it became mandatory for the employers to inform the authorities on every new vacancy, whether they needed services from the government employment agencies or not. For these reasons, it was quite clear in advance that the structure of the estimated model could not possibly have remained unaltered.

The first striking thing in the new data was that - for the first time in the 1980's - the productivity expectations published by the Ministry of Finance were quite realistic. Previously, the expected figures for the growth rate of productivity had always been far too low. This is why we had to divide the expectations for the years 1989 and 1990 by the previous average of the ratios between the actual and the expected figures. After this correction, the forecasts for the changes in the contract wages obtained from our model, were very accurate indeed. All in all, it is quite obvious that during the negotiations, the central organizations have access to much more reliable information on the growth rate of productivity than what is supplied by the Ministry of Finance four or five months earlier.

The forecasts and the actual observations of the variables w_{ij}^c, d_t^* and p_t have been displayed in Table 5. As one can see, the forecasts of w_{ij}^c are very accurate, whereas the forecasts of d_t^* are systematically too low. This is why we wanted to test formally, whether there had been a structural change in the model at the end of 1988. To this end, we derived the approximate distribution of the forecast errors according to model (3.1).

By using the notation of Section 3, let

$$\boldsymbol{Y}_* = \begin{pmatrix} Y_{n+1}^* \\ \vdots \\ Y_{n+h}^* \end{pmatrix} \quad , \quad \boldsymbol{Z}_* = \begin{pmatrix} Z_{n+1} \\ \vdots \\ Z_{n+h} \end{pmatrix} \quad ,$$

Table 5:

Forecasts and updated estimates of Model III

EQUATION	Variable	Parameter	Updated parameter estimates for Model III: Estimate	(t- value)	Forecasts: Quarter	Observed value	Forecast
Eq. I: Contract wages	constant	γ_{10}	-0.076	(-2.34)	1989/1	0.005	0.007
	p_i^e	γ_{11}	1.008	(6.64)	1989/2	0.016	0.020
	a_i^e	γ_{12}	2.534	(4.52)	1989/3	0.000	0.001
	ue_i	γ_{13}	-0.0319	(-3.95)	1989/4	0.016	0.019
	wed_i	γ_{14}	-1.220	(-4.45)	1990/1	0.009	0.007
	[$\nabla_4 D_i$]	[γ_{16}]	[-0.344]	[(-0.68)]	1990/2	0.028	0.023
					1990/3	-0.001	0.000
	Annual disturbance	τ	0.0038		1990/4	0.022	0.017
	Quarterly disturbance	σ_1	0.0032				
Eq. II: Wage	constant	γ_{20}	0.0116	(12.08)	1989/1	0.017	0.007
	$\delta_{3,t}$	γ_{21}	-0.0133	(-6.15)	1989/2	0.021	0.020
	$\nabla^* \log \tilde{P}_t$	β_{21}	0.0889	(2.55)	1989/3	-0.000	-0.006
	[$\nabla^* \log \bar{W}_{t-1}^c$]	[γ_{23}]	[-0.117]	[(-1.71)]	1989/4	0.005	0.009
	$\nabla^* vac_t$	γ_{25}	0.00000179	(3.37)	1990/1	0.016	0.011
	$\nabla^* stdw_t$	γ_{26}	0.00205	(4.77)	1990/2	0.019	0.008
					1990/3	-0.003	-0.010
	Disturbance	σ_2	0.0037		1990/4	0.012	-0.001
Eq. III: Inflation rate	constant	γ_{30}	-0.00270	(-0.46)	1989/1	0.008	-0.013
	$\dot{i}_t$	γ_{31}	0.132	(2.13)	1989/2	0.024	0.044
	p_{t-2}	γ_{32}	-0.659	(-8.09)	1989/3	0.010	0.019
	w_t	β_{30}	0.471	(5.37)	1989/4	0.014	0.007
	w_{t-1}	γ_{33}	0.496	(4.52)	1990/1	0.020	0.011
	w_{t-2}	γ_{34}	0.467	(4.65)	1990/2	0.013	0.027
	tax_t	γ_{35}	-0.002	(-0.01)	1990/3	0.009	0.237
	a_{t-1}	γ_{36}	-0.037	(-0.85)	1990/4	0.008	0.026
	Disturbance	σ_3	0.0085				

$$S_* = \begin{pmatrix} S^*_{n+1} & 0 & . & . & 0 \\ 0 & . & . & . & 0 \\ . & . & . & . & . \\ 0 & . & . & 0 & S^*_{n+h} \end{pmatrix} \quad , \quad \psi_* = \begin{pmatrix} \psi^*_{n+1} \\ . \\ . \\ . \\ \psi^*_{n+h} \end{pmatrix} \quad ,$$

$$\hat{Y}_* = Z_* \hat{\beta}_{3S} \quad \text{and} \quad E_* = Y_* - \hat{Y}_* \quad ,$$

where h denotes the number of years to be forecasted.
According to model (3.1), the distribution of the forecast errors E_* should then be multivariate normal

$$E_* \sim N_{Kkh}(0, \Omega) \quad , \tag{4.3}$$

where

$$\Omega = \mathrm{cov}(Y_* - \hat{Y}_*) = \mathrm{cov}\left((Y_* - Z_*\beta) - Z_*(\hat{\beta}_{3S} - \beta)\right)$$

$$= \mathrm{cov}(\psi_*) + Z_* \mathrm{cov}(\hat{\beta}_{3S} - \beta) Z_*' \tag{4.4}$$

$$= \mathbf{I} \otimes \Sigma \otimes \mathbf{I} + \tau^2 S_* S_*' + Z_* \mathrm{cov}(\hat{\beta}_{3S} - \beta) Z_*' \ .$$

Because $\tilde{\Sigma}$ is consistent for Σ and $\hat{\tau}_{3S}$ is consistent for τ, we can deduce from (4.3) and (4.4) that the asymptotic distribution of

$$q_h = E_*' \left[\mathbf{I} \otimes \tilde{\Sigma} \otimes \mathbf{I} + \hat{\tau}^2_{3S} S_* S_*' + Z_* \widehat{\mathrm{cov}}(\hat{\beta}_{3S} - \beta) Z_*'\right]^{-1} E_* \tag{4.5}$$

should be χ^2_{Kkh}. The quadratic form q_h can thus be used as a test statistic for testing a structural change in the wage determination mechanism.

This is what we have done with the result that for the year 1989, q_1 attained the value

$$q_1 = 20.03$$

corresponding to a p- value $p = 0.067$. For both years 1989 and 1990 we got

$$q_2 = 46.05$$

corresponding to a p- value $p = 0.004$, which shows that a structural change in the wage drift equation has indeed occurred in 1989. To see, whether the values of the parameters had changed, or whether there had been a more fundamental qualitative change in the mechanism generating the wage drift, we updated the estimates of Model III. The updated estimates have been displayed in Table 5. It is apparent that the parameter estimates have not changed much. Rather, the role of the most relevant explanatory factors $\nabla^* stdw_t$ and $\nabla^* vac_t$ have become even more accentuated than before. The fitted values produced by the updated model show the same pattern as the corresponding forecasts, i.e. they systematically underestimate the drift in 1989 and 1990. This is why we obviously have to conclude that some external factors that are missing from model (4.1) have suddenly started to influence the drift. The most obvious explanation for this unexpected acceleration of the drift is the overheating of the economy, which was partially fed by the excess supply of lending money.

In the previous sections, we have used the number of vacancies as the sole proxy for the average bargaining power of individual workers. However, for some reason or another, the employers have obviously assented to more rapidly drifting wages in 1989 and 1990 than would have been motivated solely by the steep increase in the number of vacancies at the time. Clearly, more research will be needed at this point.

5. CONCLUSIONS

There are two stages in the Scandinavian system of wage determination: First, the central organizations of the employers and of the employees negotiate the so-called contract wages branch by branch. At the second stage, individual workers or groups of workers may set forth new wage claims to their employers. In this article we have shown that it is quite possible to model the two-stage wage formation mechanism truthfully in this respect. Despite the complexity of the resulting model, the parameters can be efficiently estimated by a combination of a noniterative three-stage estimation algorithm and a grid search.

In the empirical part of our study it turned out, that it was indeed necessary to incorporate distinct error components for the annual and for the quarterly random variations in the model for the contract wage series. Our theoretical explanation for the emergence of the wage drift *was* supported by the data, because the theory was in fact capable of picking up the most relevant explanatory variables. It turned out that the state of the labour market, the heterogeneity between branches and the unanticipated inflation were the basic determinants of the drift. The two first of these variables would not have entered the model at all according to conventional theories, but they proved to be the best explanatory variables of them all.

The negotiators of the central organizations do not seem to be able to anticipate the magnitude of the drift within the commencing contract period. On the other hand, they might still possibly make a kind of nonexplicit reservation of a *fixed* percentage amount for the drift. Raises of the contract wages seem to have a weak negative effect on the wage drift during the next quarter, but no other interdependencies between these two wage fractions could be found.

The hypothesis that the proportion of workers benefitting from the drift would remain constant could not be rejected against the alternative of a linear trend.

The inflationary effects of the drift seem to be very fast indeed. About 80% of the drift seem to carry over to the domestic inflation rate within one year.

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APPENDIX A:

Form of the model (2.1) + (2.7) + (2.9):

$$
\begin{cases}
w^c_{ij} = (\gamma_{1o} + \gamma_{11} p^e_i + \gamma_{12} a^e_i + \gamma_{13} ue_i + \gamma_{14} wed_i + \xi_i)\cdot s_{ij} + \varepsilon^{(1)}_{ij} \\
d^*_t = \beta_{21} \nabla^* \log \tilde{P}_t + \gamma_{20} + \gamma_{21} \delta_{3,t} + \gamma_{22} \nabla^* \log \tilde{P}^e_t \\
\qquad + \gamma_{23} \nabla^* \log A_t + \gamma_{24} \nabla^* \log A^e_t + \gamma_{25} \nabla^* vac_t + \gamma_{26} \nabla^* stdw_t + \varepsilon^{(2)}_t \\
p_t = \gamma_{30} + \gamma_{31} i_t + \gamma_{32} p_{t-2} + \beta_{30} w_t + \gamma_{33} w_{t-1} + \gamma_{34} w_{t-2} + \gamma_{35} tax_t + \gamma_{36} a_{t-1} + \varepsilon^{(3)}_t
\end{cases}
$$

where

$$
\begin{cases}
\xi_i \sim NID(0, \tau^2) \quad , \quad \{\xi_i\} \perp\!\!\!\perp \{(\varepsilon^{(1)}_{ij} \quad \varepsilon^{(2)}_t \quad \varepsilon^{(3)}_t)'\} \\
(\varepsilon^{(1)}_{ij} \quad \varepsilon^{(2)}_t \quad \varepsilon^{(3)}_t)' \sim NID_3(0, \mathbf{\Sigma}) \quad , \\
i = \text{int}(\frac{t-1}{4}) + 1 \quad , \quad j = t - 4\cdot(i-1) \quad ,
\end{cases}
$$

and

w^c_{ij} = the logarithmic change of the contract wage index during quarter t
p^e_i = the expected rate of inflation for the year i based on the information available at the end of the previous year
a^e_i = the expected, logarithmic change of productivity for the year i
ue_i = the annual change in the unemployment rate at the end of the year $i-1$
wed_i = the annual logarithmic change of the wedge
s_{ij} = the allotment factor that measures, how large a share of the total annual increase of the contract wages is allotted to quarter j in the year i ($s_{i1} + s_{i2} + s_{i3} + s_{i4} = 1$)
d^*_t = $\nabla^* D_t$ = the wage drift
$\delta_{3,t}$ = seasonal dummy for the third quarter
$\tilde{P}^e_t$ = the expected price level (expectation formed in the beginning of the year)
A^e_t = the expected productivity (expectation formed in the beginning of the year)
vac_t = number of vacancies
$stdw_t$ = standard deviation of the average wages between 8 branches
p_t = $\nabla \log \tilde{P}_t$ = the (logarithmic) inflation rate
w_t = $\nabla \log \tilde{W}_t$ = the (logarithmic) wage increase at quarter t
i_t = $\nabla \log I_t$ = the rate of increase of the import prices
tax_t = $\nabla \log r_t$ = the (logarithmic) change in the rate of indirect taxes
a_t = $\nabla \log A_t$ = the annual (logarithmic) change in productivity

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