Discussion Paper

Research Department, Statistics Norway

No. 101 September 1993

Testing for Purchasing Power Parity and Interest Rate Parities on Norwegian Data

by

Anne Sofie Jore, Terje Skjerpen and Anders Rygh Swensen

Testing for Purchasing Power Parity and Interest Rate Parities on Norwegian Data

by

Anne Sofie Jore, Terje Skjerpen and Anders Rygh Swensen

Abstract

In this paper we are investigating the cointegrated relationships within a VAR-model containing the Norwegian inflation rate, the foreign inflation rate, the depreciation, the Norwegian short run interest rate and the foreign short run interest rate (quarterly data). Since we were unable to obtain a well-behaved equation for the change in the depreciation, we have chosen to treat the change in the depreciation as a weakly exogenous variable (with respect to the long run parameters). This is implemented by conditioning on the depreciation. Under this assumption, the residuals in the remaining equations are reasonably well-behaved. From an economic point of view our main aim is to test whether the Uncovered Interest rate Parity(UIP), the Purchasing Power Parity(PPP) and the Real Interest Rate Parity (RIRP) are contained in the cointegrating space. In the maintained model we conduct structural hypotheses under two different values for the cointegrating rank. When the cointegrating rank is set to two the PPP and the UIP hypotheses are easily rejected, whereas we cannot reject the RIRP at the 5 percent significance level. These results are somewhat modified when the cointegrating rank alternatively is set to three.

Keywords: Multivariate cointegration, Purchasing Power Parity, Uncovered Interest Parity

1. INTRODUCTION[1]

The present paper is an investigation of the relationship between prices and interest rates in Norway and abroad, and how they are related through the foreign exchange rate. The most common models of exchange rate and interest rate determination are based upon some basic equilibrium conditions: Purchasing Power Parity (PPP), Uncovered Interest rate Parity (UIP) and Real Interest Rate Parity (RIRP). Our purpose with this investigation is to look for the presence of these equilibrium conditions using Norwegian quarterly data.

I: Purchasing Power Parity (PPP) is defined by

(I.1)
$$V_t = P_t^d/P_t^f.$$

V is the nominal exchange rate, P^d a domestic price index and P^f the corresponding foreign price index. PPP is thus a relationship between the relative price indices and the level of the exchange rate.

In the so called relative version, the PPP can be stated as

(I.2)
$$V_t/V_{t-1} = (P_t^d/P_{t-1}^d)/(P_t^f/P_{t-1}^f).$$

The relative inflation rates are associated with the rate of change in the exchange rate.

II: Uncovered Interest Rate Parity (UIP) is defined by

(II.1)
$$E_t^*(V_{t+1} - V_t)/V_t = (i_{t,t+1}^d - i_{t,t+1}^f)/(1 + i_{t,t+1}^f),$$

where E^* denotes expectation. Different types of expectation formations will be discussed later. The variables i^d and i^f denote domestic and foreign nominal interest rates, respectively.

---

[1]We would like to thank Katarina Juselius for having provided us with the CATS in RATS program for maximum likelihood estimation of cointegrated systems. Furthermore we would like to acknowledge the useful comments which we have received during the Nordic Workshops on Multivariate Cointegration. Any remaining errors and weaknesses are our own.

A higher domestic interest rate relative to the foreign interest rate will be associated with an expected depreciation of the exchange rate. In the covered interest parity, the expected spot rate is replaced by the forward exchange rate. Interest rate arbitrage will ensure that the covered interest parity always will hold, given some assumptions about the absence of market imperfection. Hence, the UIP is equivalent to the hypothesis that the forward exchange rate is an unbiased predictor of the future spot exchange rate.

III: Real interest rate parity (RIRP) is defined by

(III.1) $$r^d_{t,t+1} = r^f_{t,t+1},$$

where r^d and r^f are the domestic and foreign real rates of interest, and are defined as

(III.2) $$1 + r^n_{t,t+1} = \left(1 + i^n_{t,t+1}\right) / \left(E^*_t\left(P^n_{t+1} / P^n_t\right)\right), \quad n = d,f.$$

Taking logarithms, the three parity conditions I.2, II.1 and III.1 are:

(1) $$v_{t-1,t} = \pi^d_{t-1,t} - \pi^f_{t-1,t} \qquad \text{PPP},$$

(2) $$i^d_{t-1,t} - i^f_{t-1,t} = E^*_{t-1}(v_{t-1,t}) \qquad \text{UIP, and}$$

(3) $$i^d_{t-1,t} - E^*_{t-1}\pi^d_{t-1,t} = i^f_{t-1,t} - E^*_{t-1}\pi^f_{t-1,t} \qquad \text{RIRP}.$$

In equation (1), v is actual depreciation from t-1 to t and π^d and π^f are the inflation rates from t-1 to t at home and abroad respectively. In equation (2) i^d and i^f are the nominal interest rates at time t-1 for papers with maturity 1 at home and abroad respectively. Equation (2) is an approximation of (II.1), valid for small values of i^f and i^d. Whereas equation (1) only involves actual variables, equations (2) and (3) also involve expectation of variables. A parity condition between actual variables we refer to as an ex post parity. Likewise, a parity condition which also involves expectation of variables is referred to as an ex ante parity condition. If expected depreciation is equal to actual depreciation and expected inflation rates equal to actual inflation rates, any two of equations (1) to (3) imply the third. These are the ex post relations. Furthermore, combining (2) and (3) we obtain the ex ante PPP. This equation together with equations (2) and (3) are the ex ante parity conditions. The hypotheses of PPP and UIP have usually been analyzed separately.[2] The literature concerning empirical testing of PPP is abundant. Frenkel (1978) gives an overview of the theory of PPP, and finds support for the theory on the basis of time series data from the 1920s. He also discusses the choice of price indices and the problem with simultaneity when the price indices are assumed to be exogenous, which is mostly the case. In Frenkel (1978), as in most others written in the 1970s and early 1980s, the time series properties of the data is not taken into account. After the publication of the influential paper by Engle and Granger (1987), many authors started to look for evidence of PPP using Error Correction Models. Some authors find some support for PPP as a long run relation (cf for instance Edison and Klovland (1987), Kim (1990) and Fisher and Park (1991)). In other papers, Layton and Stark (1990) and Patel (1990) little support for PPP is found.

When focusing on PPP and UIP within a long-run framework, however, it may be fruitful to include all variables entering potential PPP and UIP relations. For instance, a deviation from PPP may significantly influence the development of the domestic interest rate, thus the reduced form for this variable may contain useful information about the PPP relation. Our paper follows the approach taken by Johansen and Juselius (1992a), utilizing the cointegration results outlined in Johansen (1991). Using the same type of data, we test, within a VAR-framework, whether we can condition on some of the variables without loosing significant information about the long-run parameters. If the analysis indicate that some of the vectors contained in the cointegration space can be given meaningful interpretations from an economic point of view, a natural next step would be to freeze the long-run parameters and simplify the short-run behaviour within a stationary framework using the maximum likelihood procedure advocated by Hendry (1988).

The method we shall consider consists of first fitting an unrestricted VAR model to the data. It is possible under assumptions which seems to be fulfilled in the situation we consider to interpret some of the parameters as describing the long run properties of the process. This

---

[2] In Baillie and McMahon (1989) some examples of tests for UIP are given. The authors here point out that most of these empirical tests are based on the assumption that the interest rate differential is exogenous. The results are then likely to be biased, since the UIP is a relation between endogenous variables.

makes it possible to test whether the above relations correspond to such long-run properties of the data generating process.

The general VAR model is given by

$$(4) \qquad Z_t = \Pi_1 Z_{t-1} + \Pi_2 Z_{t-2} + \ldots + \Gamma_k Z_{t-k} + \Phi D_t + \mu + \varepsilon_t.$$

In (4) Z_t is a p dimensional vector of observable variables, whereas D_t is a vector of centered seasonal dummies and other conditioning variables. The vector ε_t are independent p-dimensional Gaussian variables with mean zero and covariance matrix Ω. We assume that $Z_0, \ldots, Z_{-k+1}$ are known. An equivalent formulation of (4) highlighting the differences is

$$(5) \qquad \Delta Z_t = \Gamma_1 \Delta Z_{t-1} + \ldots + \Gamma_k \Delta Z_{t-k+1} + \Pi Z_{t-k} + \Phi D_t + \mu + \varepsilon_t$$

where $\Gamma_i = -I + \Pi_1 + \ldots + \Pi_i \quad i = 1, \ldots, k+1$

and $\Pi = -(I - \Pi_1 - \ldots - \Pi_k)$.

This is the so called interim multiplier representation and is just a convenient reparameterization of (4).

One of the basic features of the data we look at in this paper is that although the levels exhibit a rather strong trend, the differences look stationary. If we want models like (5) to reflect this, Π cannot be of full rank.

Thus a natural assumption is that Π has rank r, $0 < r < p$. Then it can be written as

$$\Pi = \alpha \cdot \beta'$$

where α and β are p×r matrices of full rank, where $0 < r < p$.

Inserting this into (5) we get

$$(6) \qquad \Delta Z_t = \Gamma_1 \Delta Z_{t-1} + \ldots + \Gamma_{k-1} \Delta Z_{t-k+1} + \alpha\beta' Z_{t-k} + \Phi D_t + \mu + \varepsilon_t.$$

Let $\Pi(z)$ be the characteristic polynomial associated with the models (4) and (5), i.e.

$$\Pi(z) = (1-z)I - \sum_{i=1}^{k-1} \Gamma_i(1-z)z^i - \Pi z^k.$$

Under the additional assumption that z=1 or |z|>1, i.e. that the roots are either outside the unit circle or exactly in 1, the difference equations in (4) and (5) may be solved. This is done in Johansen (1991). It turns out that in this case the differences are stationary and so are the linear combinations $ß'Z_t$.

This points to a nice interpretation of (6) as an error correction model. The vector $ß'Z_{t-k}$ describes to which extent the process is out of long-run equilibrium, whereas the α-matrix express the reduced form reaction to this equilibrium. The model (6) is not identified in the usual sense. To emphasize this let A be a non-singular matrix with dimension rxr and let us define

$$\alpha^* = \alpha A \quad \text{and} \quad \beta^{*\prime} = A^{-1}\beta'$$

Since α^*, $ß^{*'}$ will give the same likelihood value as the pair α, ß', it is evident that only the space spanned by the vectors of α and ß can be identified unless we want to impose some a priori restrictions on either of the matrices.

Returning to model (6), it turns out that the unknown parameters may be estimated. For the details we refer to Johansen and Jurelius (1990) and Johansen (1991).

Using the results above the value of the maximized likelihood can be derived for various r. This allows testing for the value of r. Once the dimension of the cointegration space, r, is determined various tests can be performed describing the space spanned by α and ß. How this is carried out is described in the papers just mentioned.

In this paper data consists of time series of inflation, the exchange rate and interest rates. The equilibrium relations we consider are those described in equations (1) to (3). It should, however, be emphasized that stationarity of the linear combinations in (1) - (3) are only necessary conditions for the validity of the parity conditions. In addition they should be stationary around zero. This can be tested formally, but is not done in this paper.

The UIP and RIRP involves expectational variables: The UIP is a forward looking statement about the relationship between foreign and domestic interest rates and the expected depreciation. The RIRP states that there is equality between the ex ante real interest rates, and thus involves expected inflation rates. Unfortunately, no data on expected depreciation and inflation are available in Norway.

Due to this lack of data for expectations of the depreciation and the inflation rates, we have to use proxies for these variables. Two possibilities are explored. The first alternative is naive expectations - a simple form of adaptive expectations, i.e. the expected depreciation and inflation rates in a period equals the observed values of the previous period. In this case the equilibrium relations (2) and (3) takes the form

$$(2)' \qquad i^{d}_{t-1,t} - i^{f}_{t-1,t} = v_{t-2,t-1}$$

and

$$(3)' \qquad i^{d}_{t-1,t} - \pi^{d}_{t-2,t-1} = i^{f}_{t-1,t} - \pi^{f}_{t-2,t-1}.$$

A second alternative is to assume model consistent expectations. This means that the expectations are assumed to be equal to the probabilistic conditional expectations in the fitted VAR model. The interpretation is that economic agents are using all available information (i. e. information on inflation rates, depreciation and interest rates together with other exogenous variables included in the model) to forecast future variables. How this may be implemented is explained in some detail in appendix A. It turns out that the relations (2) and (3) in this case are equivalent to (2)′ and (3)′ plus some extra conditions involving the parameters describing the short run dynamics. Thus (2)′ and (3)′ are necessary conditions for (2) and (3) when the expectations are interpreted as model consistent expectations. Furthermore, it may also be shown that within a long-run framework the distinction between ex ante RIRP and ex post RIRP is not important. The ex ante RIRP involves the expected inflation rates. To test whether the real interest rate differential is stationary, the expected inflation rates are replaced by lagged inflation rates. It is, however, quite easy to recast the VAR model in such a way that the actual instead of the lagged inflation rates enter the long run part of the model. Again the two models are only different with respect to the short run implications. It should, however, be emphasized that the interpretation based on model consistent expectations only can be invoked by modelling all the variables which are entering the parity conditions. This requirement is not fulfilled in our models, since we had to condition on the depreciation in order to get well-behaved residuals.

The plan for the remaining of the paper is as follows. In section 2 we describe the choice of data to represent our theoretical variables. Section 3 is devoted to residual analysis of selected models. In section 4 we determine the cointegrating rank in the maintained model from section 3. Section 5 contains the structural analysis of the cointegrating vectors. In section 6 we report some results for the loading factors. Finally, our conclusions are presented in section 7.

2. THE DATA

There are numerous possibilities when choosing the relevant variables. One possibility is to look for bilateral parities, another to look for parities vis a vis some average of trading partners. In the case of Norway, the value of a currency basket as a measure of the exchange rate seems to be more relevant than bilateral exchange rates. Norway's foreign trade is not overly dominated by one single country.

In 1978 Norway left the European currency "snake" and introduced a national currency basket. The weights were based upon the relative importance of Norway's trading partners. Due to Norway's oil activities, the weight attached to the US dollar was higher than accounted for by Norwegian trade with USA. In principle, the target value of the currency basket was fixed, with some swing margin. In reality, however, there were several changes in the target value from 1979 to 1986. Since 1986, however, the target value remained fixed, and only quite small deviations were tolerated. In October 1990, the weights in the currency basket were changed to ECU-weights. Our observation period is thus determined by the interval between leaving the "snake" and linking to the ECU. The depreciation is measured from the previous quarter.

The theory of PPP does not state specifically what kind of price indices that are relevant. The consumer price index and the producer price index are frequently used. We have chosen the consumer price index[3] as the overall price measure - the foreign price index is a weighted average with the same weights as in the currency basket. The inflation rates are measured from the previous quarter.

[3] Frenkel (1978) discusses the different choices of price indices in some detail. In his empirical analysis, several different price indices are investigated. Layton and Stark (1990) favour the consumer price index for several reasons, the most important being that this index is the most broadly based. However, as Patel (1990) points out, the consumer price index may be integrated of order 2, and thus need differencing twice to be stationary.

We have chosen to use the average 3 month euro rate as a representative of the Norwegian short term interest rate, due to some lack of data. Studies indicate that the euro-rate is fairly close to the money market rate (Vikøren (1991)). The NOK rate with 3 months maturity will then represent the short term money market rate. The foreign interest rate is a weighted average of foreign short term euro rates - with 1 to 3 months maturity, and the weights are equal to the currency basket weights.

There are some special features in the Norwegian economy that may result in deviations from the parity conditions (1) to (3):

(i) Changing policy regimes and capital control.
In the second half of the 1980s, the government's target has obviously been to maintain the foreign reserves and the exchange rate. The interest rate has been allowed to fluctuate to ensure that the foreign reserve is in no danger of being reduced significantly. In the years preceding this, the government had stated objectives both concerning interest rates and amount of domestic credit, in addition to a fixed target value of the exchange rate. One way of interpreting this could be that despite the government objective, the foreign reserve must still have been the underlying target, although not explicitly stated. Several devaluations in this period are an indication of this interpretation. Capital controls were gradually removed from the end of the 1970s. It is difficult to take into account all the stages of changing regulations, but the bottom line is that if some capital movement is allowed, there are always ways to circumvent most of the remaining rules.

(ii) The drop in the oil prices in the middle of the 1980s.
The fall in the oil prices led to a severe deterioration of Norway's current account and led to the devaluation of Norwegian currency by some 10 per cent in May 1986. The magnitude of these events may have caused deviations from the parities. Due to the relatively short period of estimation, this could destroy the evidence of the parities (if they indeed exist). If this is the case, some indications may be found looking at the residuals. If the single equations statistics indicate misspesification, conditioning on the change in the ratio between the current account and GDP may improve the behaviour of the residuals.

(iii) Price and wage freezes during the estimation period.

Several prize and wage freezes and other forms of income control occurred through, and immediately preceding, the estimation period. In theory, this should be reflected in the interest rates and the exchange rate. However, these policies may not have been fully incorporated. Hence, we will allow for a dummy variable to take account of this if the single equations statistics indicate that some information is missing. The price freeze variable both take account of the sudden impact of the introduction of the price and wage freezes and of the subsequent catching-up effect. The variable is defined in the following way: It takes the value 1 in all the quarters of 1979 and in the fourth quarter of 1981, the value -1.5 in the first quarter of 1980, the value -1 in all quarters of 1980 except the first one and in the 1. quarter of 1982. In all the other sample points the value is 0.

Graphs of the timeseries in the VAR-part of the models are shown in figures 1 to 5. As predetermined variables in the models we are also using the change in the ratio between the current account and the GDP and a price freeze variable. The time series for the ratio between the current account and the GDP and its first difference are depicted in figure 6.

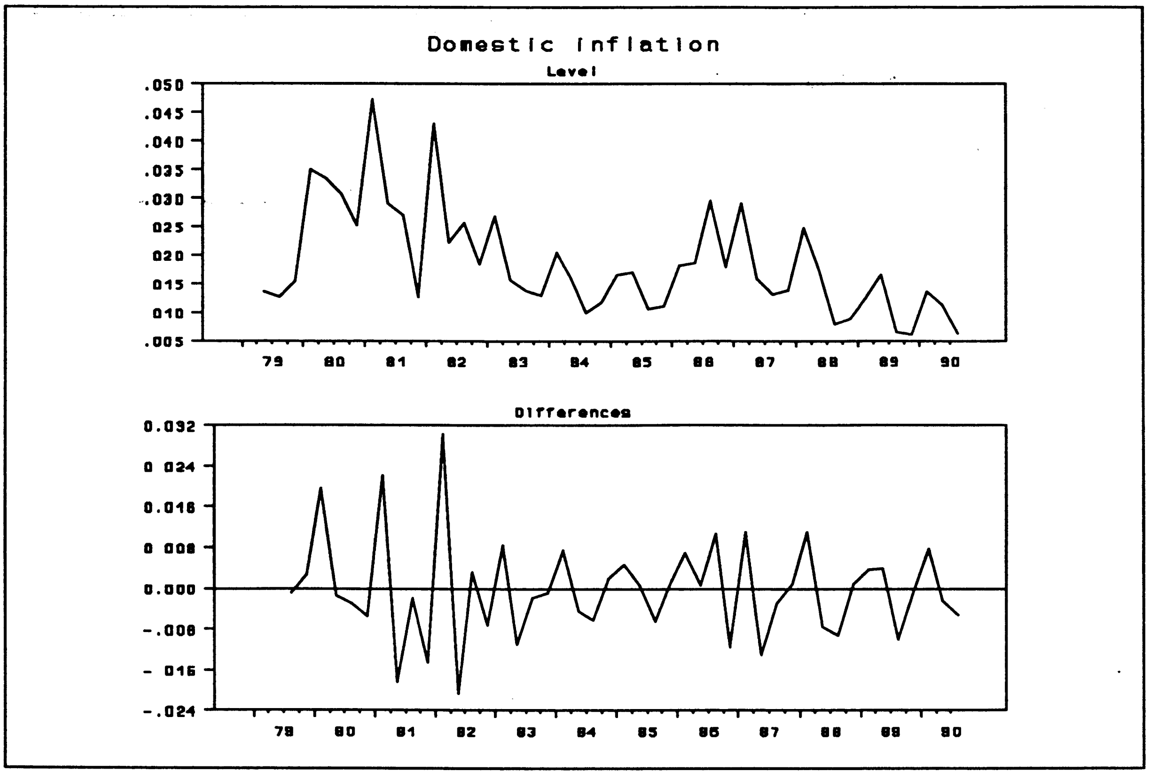

FIGURE 1: Domestic inflation

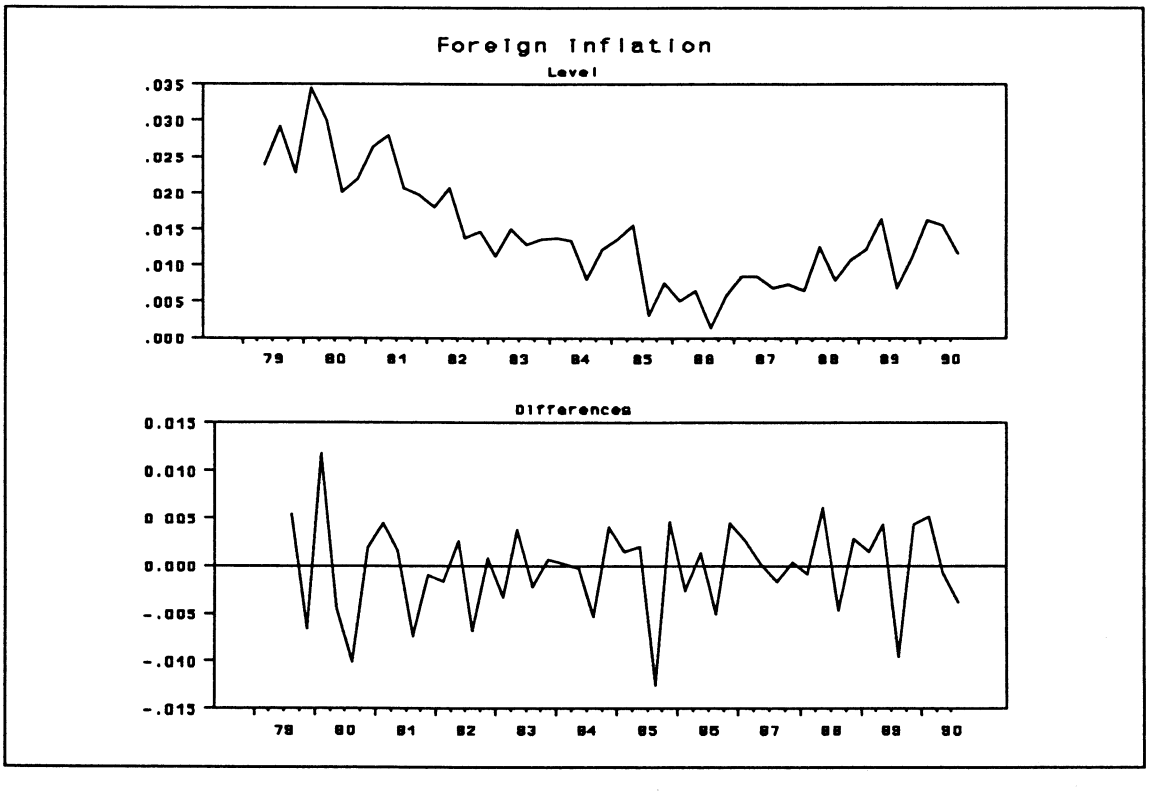

FIGURE 2: Foreign inflation

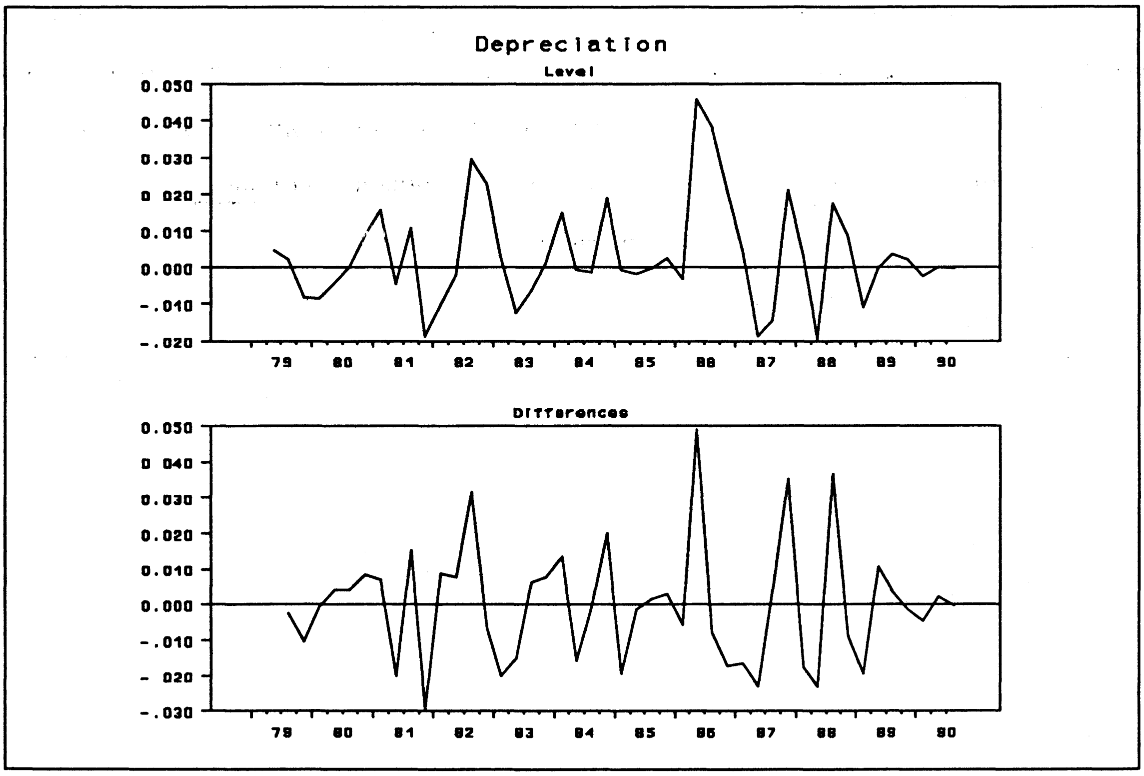

FIGURE 3: Depreciation

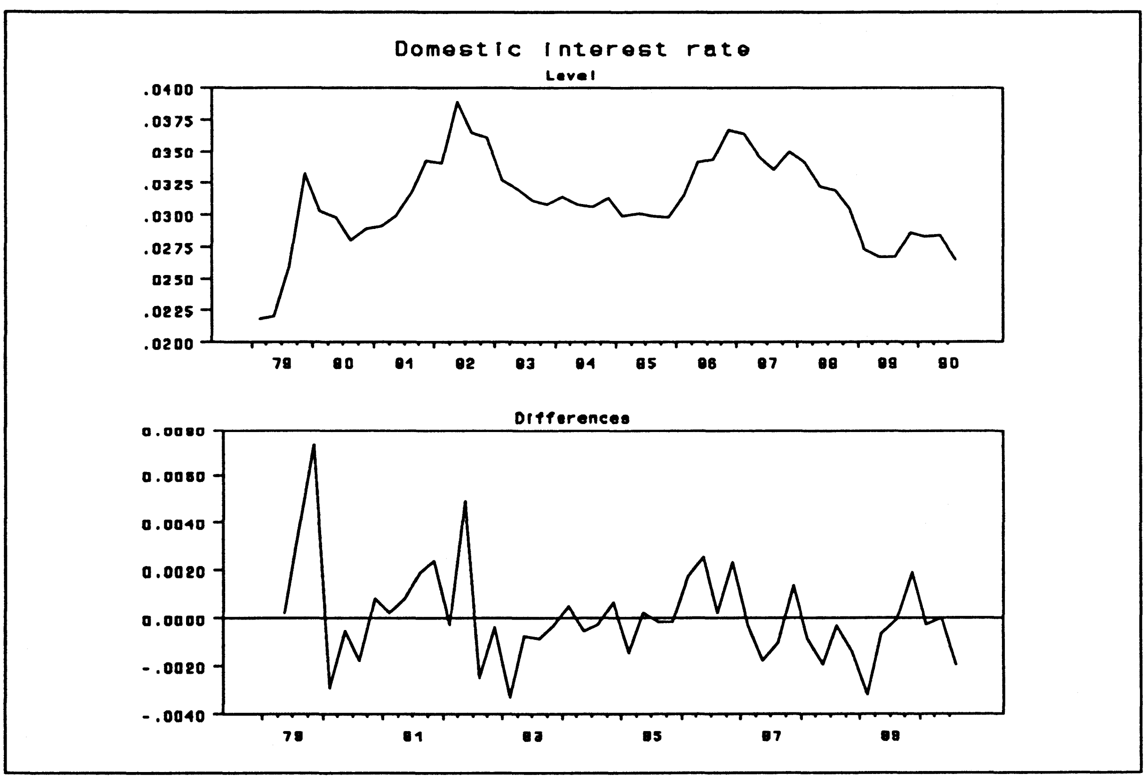

FIGURE 4: Domestic interest rate

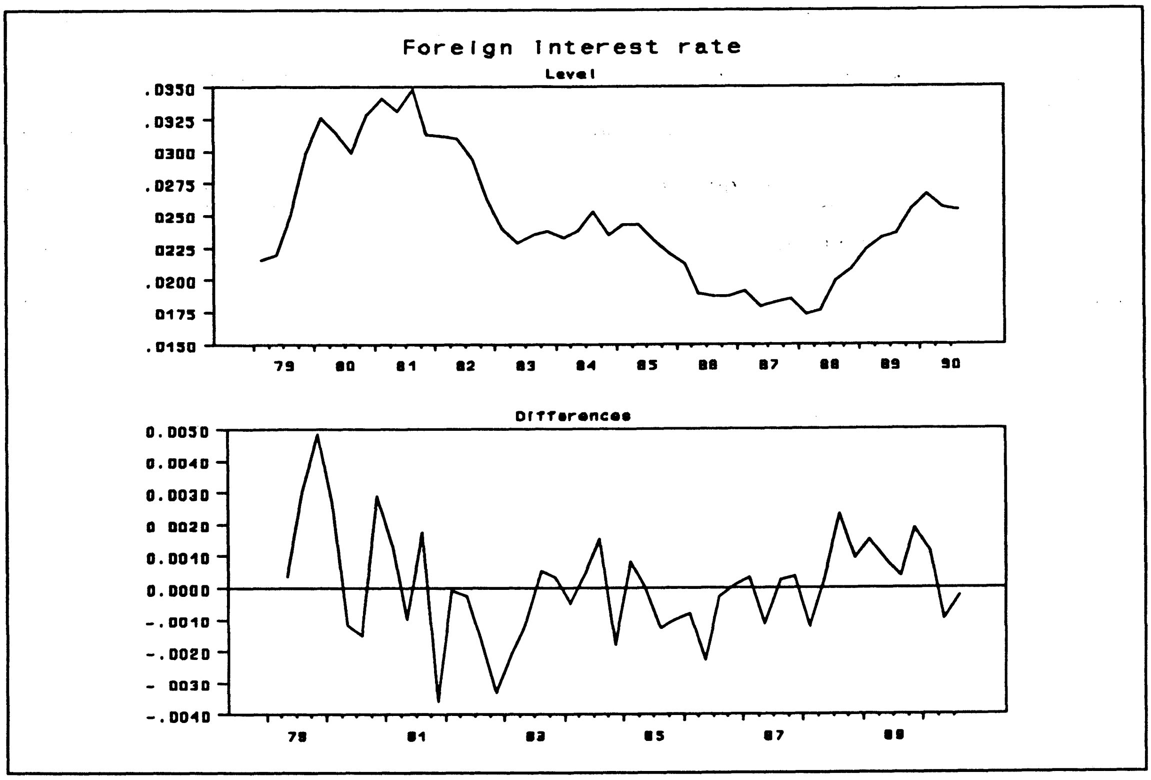

FIGURE 5: Foreign interest rate

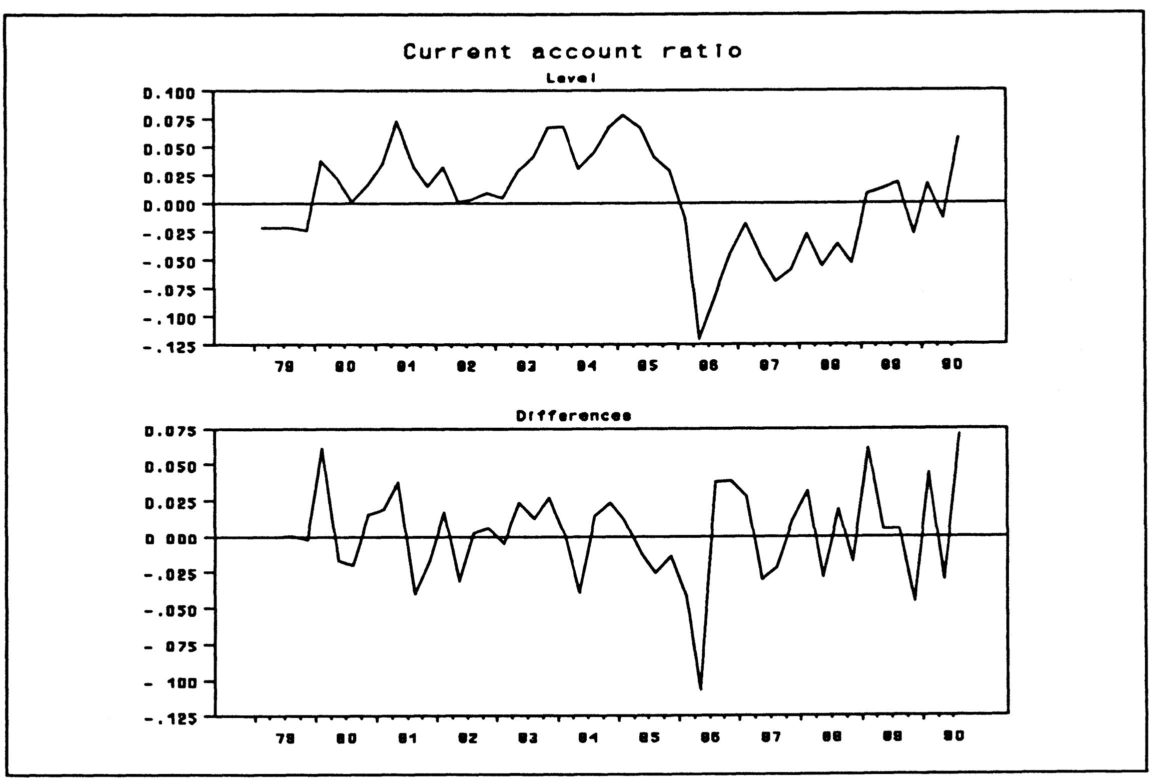

FIGURE 6: Current account ratio

3. INTRODUCING THE VAR-MODEL

As explained in the introduction, the point of departure is fitting a VAR model to the data series. In this section we comment on how this fitting has been implemented. The Z_t-vector is of dimension 5 and consists of the following components:

$$Z_t = (\pi_t^d, \pi_t^f, v_t, i_t^d, i_t^f)'$$

Instead of using the variables P_t^d, P_t^f and V_t as the three first components, we are using the first differences of their respective logarithms. This procedure may, however, imply loss of information. The price levels, the current exchange rate and the interest rates seem to have different time series properties with regard to the order of integration. Our initial differencing of the three first components of the Z_t vector facilitates joint structural tests of the different parity conditions, which involves both level and differenced variables. The fact that the inflation rates seem to contain a stochastic trend means that the price levels have to be differenced twice in order to be stationary. Recently Johansen (1992a) has shown how such variables can be dealt with within the reduced rank VAR-model. This is the socalled I2-analysis. A special interesting feature of the I2-analysis which is highly relevant in our applications is the possibility of polynominal cointegration, which means that one can have stationary combinations which includes both level and differenced variables. The I2-analysis of our data will be left for a later paper.

Our main aim in this section is to establish a well-behaved VAR-model for the components of Z_t. Thus we want the error vector to be an innovation with respect to the information set. To study the properties of the residuals we employ different misspecification statistics, all being chi-squared distributed. The Box-Pierce Q-statistic with DF degrees of freedom (B.P-Q(DF)) is used to test for serial correlation in the residuals, the ARCH statistic with DF degrees of freedom (ARCH(DF)) is used to test for autoregressive conditional heteroscedasticity in the residuals and finally the Bera-Jarque statistic (BJ), which always has two degrees of freedom, is applied to test for non-normality in the residuals. In appendix B table B1 we report these three misspecification statistics together with the coefficient of multiple correlation (RSQ) for some selected models. To improve the residual behaviour of a model it is usual to work along two lines. Extending the order of the VAR-model tends to reduce the serial correlation of the residuals, whereas autoregressive conditional heteroscedasticity and non-normality are best dealt with by introducing variables to be conditioned upon. As conditioning variables in this paper, in addition to a constant term and three centered seasonal dummy variables, we have included a price freeze dummy variable and the change in the ratio between the current account and the GDP, from now on called the current account ratio.

At the outset we tried to model all the five components of the Z_t-vector using a VAR-model with two lags. The upper left part of table B1 in appendix B shows the single equation statistics in the model version where only the constant term and the centered seasonal dummies are used as predetermined variables. As can be seen from the table, we are faced with serial correlation in the equation for the change in the domestic interest rate and with non-normality in the equations for the change in the domestic inflation and in the change of the depreciation. At the right upper part of table B1 we use a price freeze variable and the change in the current account ratio lagged two periods as additional predetermined variables. As may be inferred we have now got rid of the significant serial correlation in the equation for the change in the domestic interest rate, and there is no more sign of non-normality for the change in the domestic inflation. The non-normality in the equation for the change in the domestic inflation has been removed by conditioning on the price freeze variable. However, the remaining problem is the equation for the change in the depreciation. In this model we have significant serial correlation and non-normality for this variable. In spite of a lot of experimentation, we have not been able to establish a model where the residuals in this equation is well-behaved. On the basis of this result we fitted a model in which we conditioned on the depreciation. This corresponds to restricting all α's in the equation for the change in the depreciation to zero. (For a discussion of cointegration in partial systems confer Johansen (1992b)). If these restrictions are valid, no information about the long run parameters are lost by conditioning and the variable is weakly exogenous (in the sense of Engel, Hendry and Richard (1983)) with regard to the long run parameters. The above assumption implies that the change in the depreciation will not react to deviations from possible eventually economic meaningful parity conditions, and that all adjustment, for instance in order to reduce the deviation from the PPP, must take place in the domestic inflation rate. It may be difficult to defend such an assumption since it is not hard to argue that the exchange rate will react to the deviation. However, it is unrealistic to assume, as is implicitly done within the VAR-context, that the adjustment is continuous since several adjustments in the sample period have taken the form of devaluations. This means that we are in a situation in which the exchange rate only adjusts discretly. Of course a VAR-type model will not be capable of picking up this pattern.

The single equation statistics for the model where we have conditioned on the depreciation are given at the bottom of table B1 in appendix B, whereas graphs and correlograms of the residuals are displayed in appendix C. Under the weak exogeneity assumption referred to above the residuals in the remaining equations seem rather well-behaved, and our further analysis will be based on this model.

Writing the four dimensional VAR model in a companion form (i.e. after assuming the change in depreciation to be weakly exogenous with respect to the long run parameters), the roots of the characteristic polynomial may be found as the inverse of the eigenvalues of the matrix of the system. We have done this in our maintained model and for the rank of the impact matrix (cf appendix A) equal to 4, 3 and 2. The inverse values are displayed in table B2 in appendix B. From this table it is inferred that all the roots are to be found in the stationary area or on the unit circle. Our experience with this data set indicates that the estimated roots are rather sensistive to the lag order. In some models based on a lag order of three, for which we report no results, some of the eigenvalues are in the explosive area which we interpret as an indication of overparameterization. Thus with our rather short sample the lag order should not exceed 2.

4. DETERMINATION OF THE RANK PARAMETER (r)

In the subsequent structural analysis our focus is on the long-run impact matrix Π. The reduced rank of the Π-matrix may be implemented by using the decomposition $\Pi=\alpha\beta'$, where α and β are both pxr matrices and where $r<p$. The expression $\beta'Z_t$ may be interpreted as linear combinations of the level variables, which are stationary. Later we investigate whether these may be given meaningful interpretations from an economic point of view. The α-matrix contains the adjustment parameters which express the feedback effects from being out of the equilibrium, which is measured by $\beta'Z_t$.

Weak exogeneity of the long run parameters implies that this feedback is not present for a variable and is thus equivalent to setting the corresponding row in the α matrix equal to zero.

In this section we investigate on the rank of the long-run impact matrix Π in our maintained model. Since we fit models in which we condition on the depreciation, the maximum rank is four. The determination of the rank is based on an evaluation of the size of the eigenvalues obtained from a generalized eigenvalue problem as described in Johansen and Juselius (1990) and Johansen (1991). However, since we have conditioned on a price freeze dummy and the lagged change in the current account ratio and the critical values do not take this conditioning into account, we will not report any significance values of these test statistics. We obtain the following four eigenvalues given in descending order: (0.734, 0.631, 0.226, 0.045). As can be seen from this it is a substantial gap between the second and the third eigenvalue pointing to a cointegrating rank of two. The question thus seems to be whether the third eigenvalue can be set at zero. Table B2 in appendix B also includes some information with regard to the cointegration rank. In the right part of the table the inverses of the roots of the characteristic polynomials in the "full rank" case are displayed. The highest modulus is 0.87 corresponding to a real root followed by a complex root with modulus 0.81. Restricting the cointegrating rank to three means forcing one of the roots to be 1. Using a cointegrating rank of two means forcing another root to be 1. Since valid reduction should permit no substantial change in the dynamics, it may be the case that the cointegrated rank should be reduced only to 3. In the structural analysis of the next section our main assumption will be a cointegrating rank of two, but we will, in the light of the information above, also comment on the test results when the cointegrating rank is set to three.

Table 1

Normalized estimates of ß and α

i	$ß_{i1}$	$ß_{i2}$	$ß_{i3}$	α_{i1}	α_{i2}	α_{i3}
1	1.000	1.000	1.000	-0.259	-0.071	-0.035
2	-2.232	0.394	-1.408	0.044	-0.119	0.146
3	-0.211	-0.232	-0.256	0*)	0*)	0*)
4	0.519	-2.238	-1.836	0.001	0.163	-0.004
5	2.525	-1.068	-0.846	-0.076	0.085	0.056

*) A priori assumption

Table 1 displays the unconstrained, normalized estimates of β and α and figures 7-9 depict the accompanying unconstrained cointegrating vectors. In the lower part of these figures, the relations have been corrected for short term variation and deterministic effects. The cointegrating vectors have arbitrarily been normalized with respect to the first component in the data vector. When the cointegrating rank is set to two the third β- and α-vector are omitted so that π is only based on the two first vectors of the β- and α-matrix respectively.

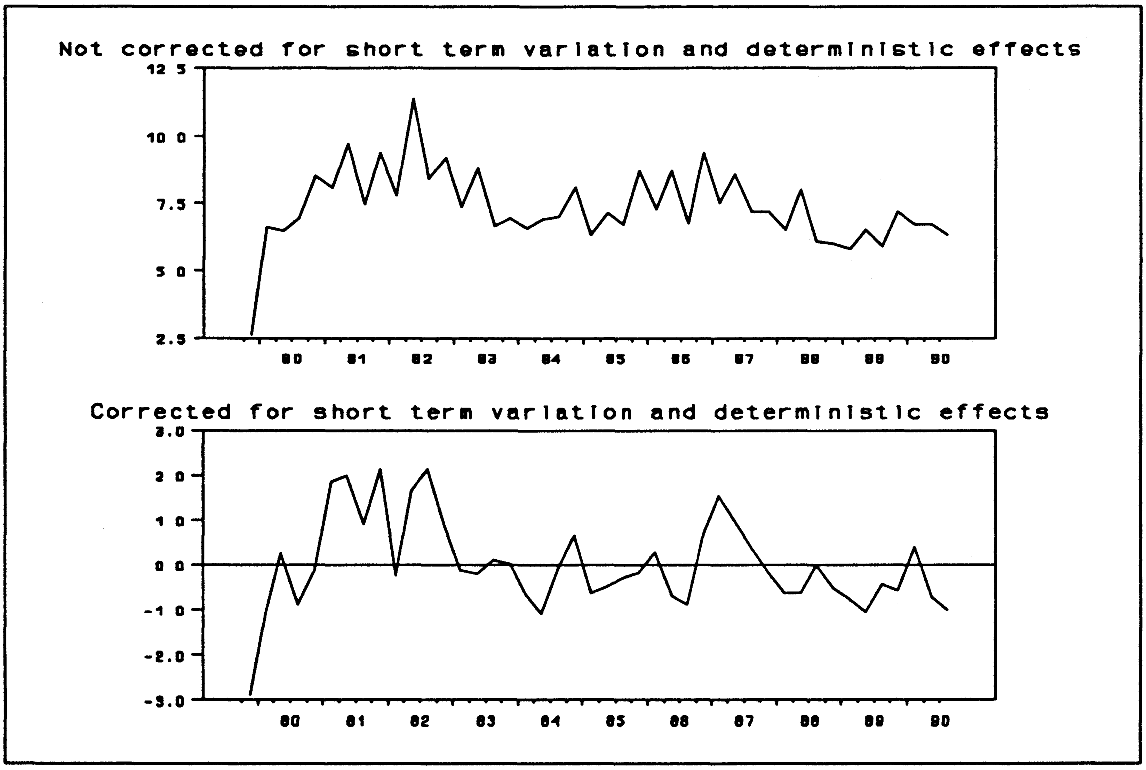

FIGURE 7: The first cointegation vector

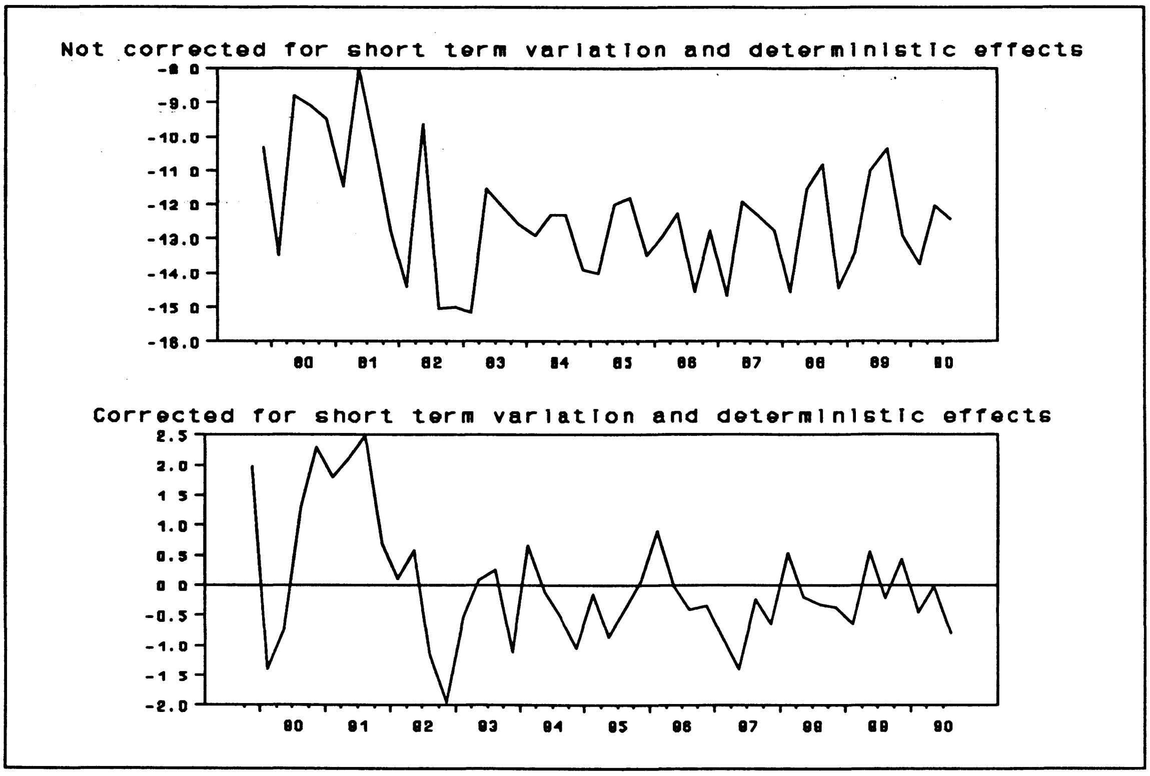

FIGURE 8: The second cointegration vector

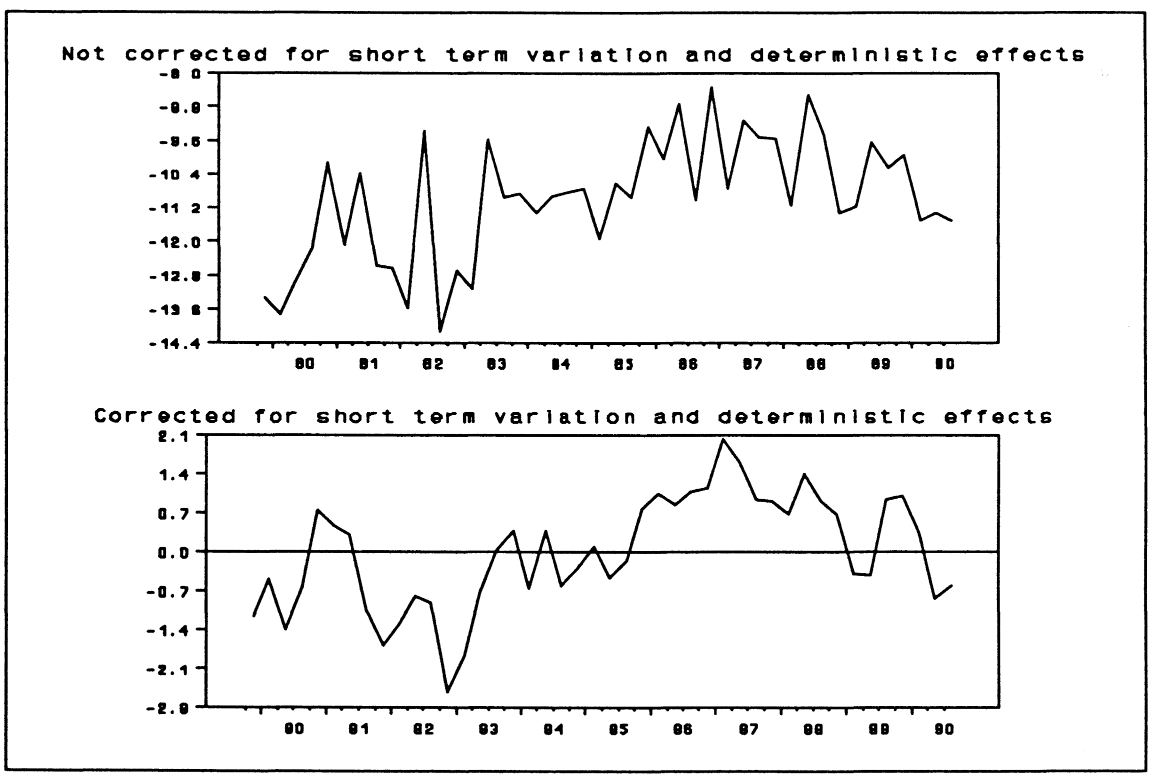

FIGURE 9: The third cointegration vector

5. STRUCTURAL ANALYSIS OF THE COINTEGRATING VECTORS

Structural test results for two different models, based on a cointegration rank of two and three respectively, are displayed in table 2. The tests consist of imposing various linear restrictions on the β vector. How this is done is explained for the full model in Johansen and Juselius (1990) and Johansen (1991) and for the partial systems we consider in Johansen (1992). In the following we will discuss some of the indicated test results. When the cointegrating rank is two, no support is found for the PPP and the UIP hypotheses. The respective significance probabilities are very close to zero. Test number 6 indicates that we cannot reject the hypothesis that the linear combination corresponding to the RIRP is contained in the cointegrating space. This linear combination may also be viewed as a linear combination of the domestic and the foreign real interest rates. In test number 7 and 8 we test whether these real interest rates themselves can be regarded as stationary variables. For the foreign interest rates there is no sign of stationarity, whereas the significance probability connected to the hypothesis that the domestic real interest rate is stationary is 0.03.

When we allow for a third cointegrating vector, which is somewhat questionable, the above results are somewhat modified. The significance probabilities connected to the hypotheses that the linear combinations corresponding to the PPP and the UIP are stationary are 0.01 and somewhat below 0.01 respectively. From test number 4 and 5 it follows that we can neither reject the hypothesis that the inflation rate difference nor that the nominal interest rate difference is stationary at the 10 percent significance level. These hypotheses were clearly rejected in the rank two cases. The significance probability connected to the hypothesis that the linear combination corresponding to the RIRP is stationary is 0.03. This is somewhat lower than in the rank two case. The significance probabilities connected to the stationarity of the domestic and foreign real interest rates are 0.11 and 0.07 respectively. In the two last tests of table 3, we are testing whether two known interpretable vectors both are contained in the cointegrating space. In the rank equal to two case, we thereby test whether these vectors span the entire cointegrating space. In test number 10 we test whether the depreciation and the linear combination corresponding to the RIRP both are contained in the cointegrating space, whereas in test number 11 the linear combinations corresponding to the PPP and UIP are subjected to the same type of test. In the case with cointegrating rank equal to two we get a clear rejection of both hypotheses. When the cointegrating rank is set to three the significance probabilities are 0.02 and 0.03 respectively. The graphs of the linear combinations corresponding to the PPP, UIP and RIRP are displayed in figures 10-12, respectively. The lower part of each figure displays the linear combinations after correction for short term variation.

When judging the above test results it should be clear that the test statistics are only asymptotically chi-squared distributed if the depreciation is weakly exogenous with respect to the long-run parameters. In our case this does not seem to be the case, but since we were unable to obtain an adequate reduced form equation for the change in depreciation we cannot offer a test of the relevant weak exogeneity assumption. If the weak exogeneity assumption fails, then testing linear restrictions on the cointegrating space involves non-standard distributions which depend on the actual β-values themselves. These distributions can be found by stochastic simulations (cf. Johansen (1992)). In the above statistical inference we found more support for the long run RIRP than for the long run PPP and the long run UIP. Viewing figures 10-12, however, it is hard to see why the linear combinations corresponding to the PPP and the UIP are less stationary than the one corresponding to the RIRP. This feature emphasizes the problems inherent in using the critical values from the chi-square distribution in question when making statistical inference.

Table 2

Testing structural hypotheses on cointegrating vectors in a VAR-model with k=2. The depreciation is assumed to be weakly exogenous.

Test number	Restrictions on cointegrating vectors	Interpretations of vectors assumed stationary	r = 2		r = 3	
			χ^2(DF)	Significance probability	χ^2(DF)	Significance probabality
1.	(0,0,1,0,0)	Depreciation	42.70 (3)	0.00	10.78 (2)	0.00
2.	(1,-1,-1,0,0)	Purchasing power parity	41.95 (3)	0.00	10.44 (2)	0.01
3.	(0,0,-1,1,-1)	Uncovered interest rate parity	41.08 (3)	0.00	10.61 (2)	0.00
4.	(1,-1,0,0,0)	Inflation difference	32.46 (3)	0.00	4.28 (2)	0.12
5.	(0,0,0,1,-1)	Interest rate difference	26.38 (3)	0.00	3.88 (2)	0.14
6.	(-1,1,0,1,-1)	Real interest rate parity	6.96 (3)	0.07	6.77 (2)	0.03
7.	(-1,0,0,1,0)	Domestic real interest rate	8.83 (3)	0.03	4.38 (2)	0.11
8.	(0,-1,0,0,1)	Foreign real interest rate	24.99 (3)	0.00	5.30 (2)	0.07
9.	(a,-a,-a,b,-b)	A combination of purchasing power parity and the interest rate difference	23.51 (2)	0.00	3.84 (1)	0.05
10.	(-1,1,0,1,-1) (0,0,1,0,0)	Real interest rate parity Depreciation	48.85 (6)	0.00	12.18 (4)	0.02
11.	(1,-1,-1,0,0) (0,0,-1,1,-1)	Purchasing power parity Uncovered interest rate parity	46.96 (6)	0.00	10.66 (4)	0.03

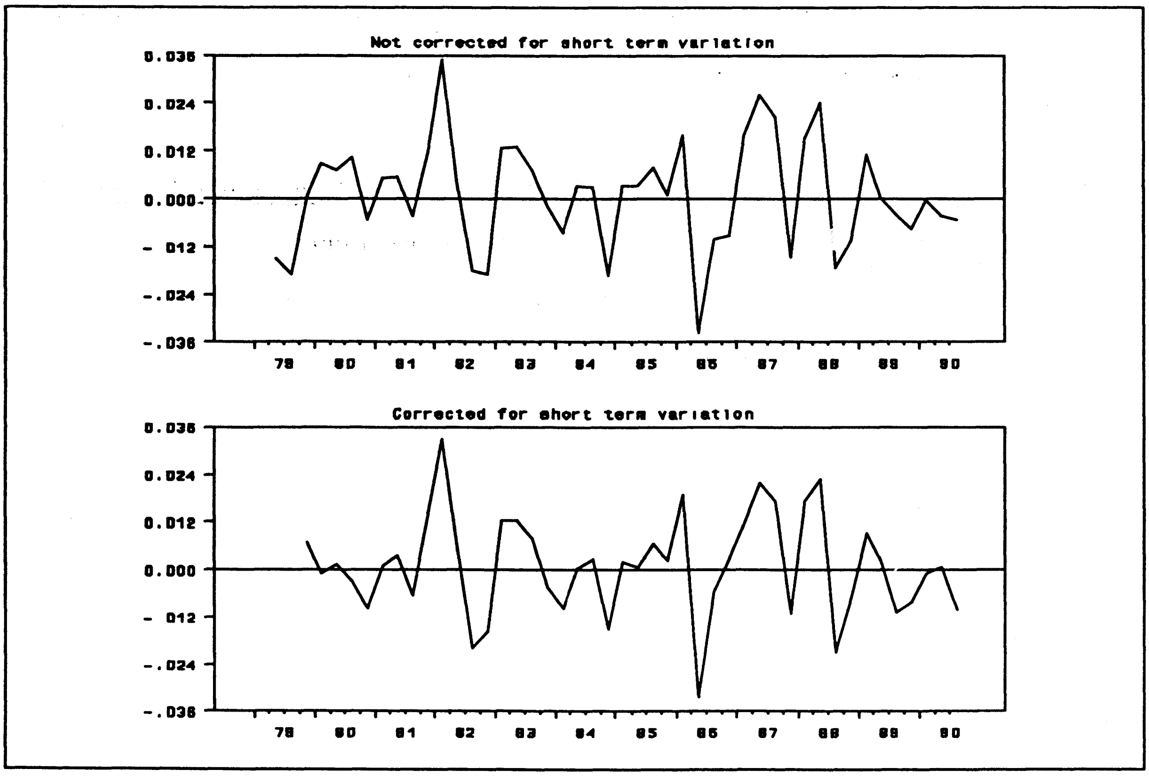

FIGURE 10: The linear combination corresponding to the PPP

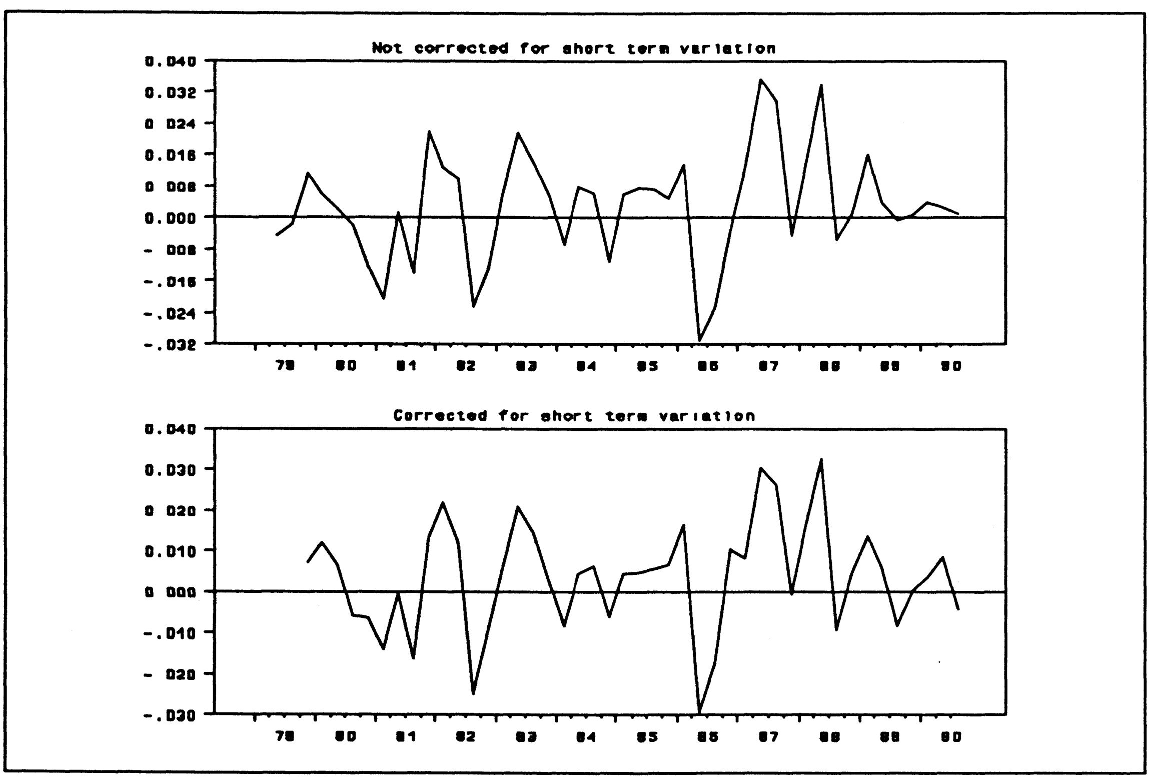

FIGURE 11: The linear combination corresponding to the UIP

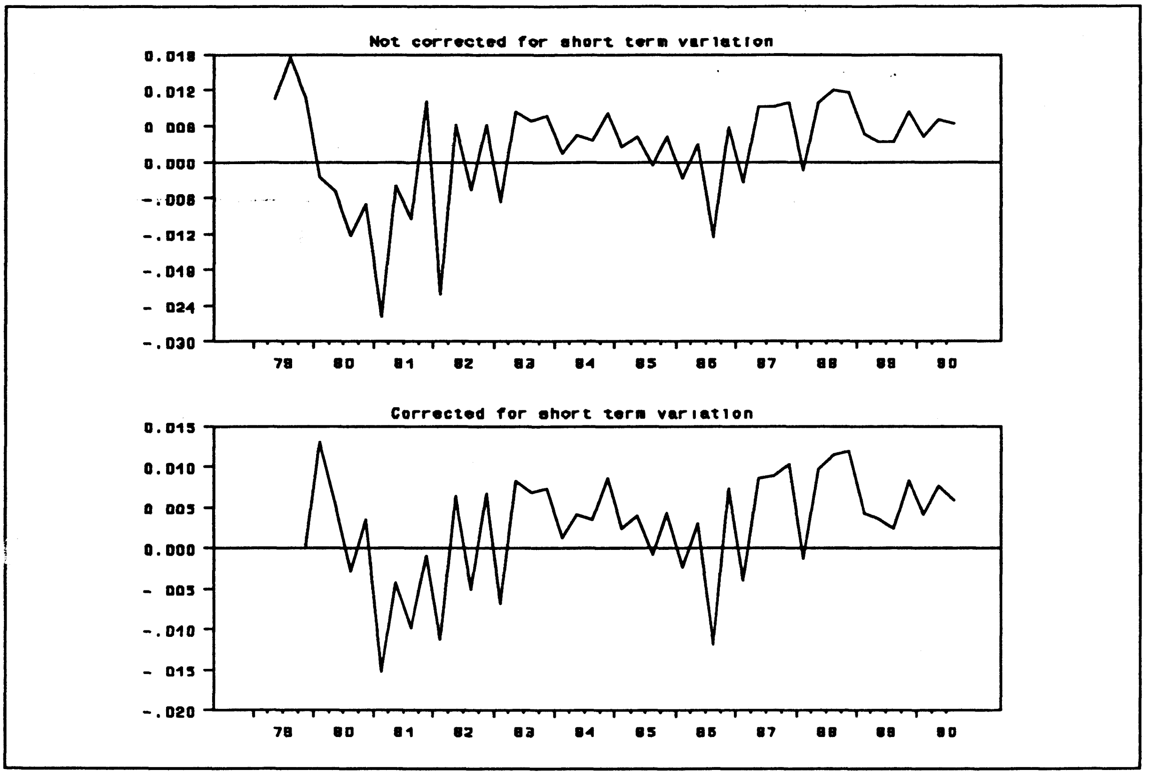

FIGURE 12: The linear combination corresponding to the RIRP

6. THE ADJUSTMENT PARAMETERS

In table 3 we report the estimates of the adjustment parameters in the case where we have imposed the linear combination corresponding to the RIRP as a cointegrating vector when the rank is two. The other vector, which seems hard to interpret from an economic point of view, is chosen orthogonal to the "economic" one. According to the test results discussed earlier, we were unable to reject the hypothesis that the real interest rate difference was present in the cointegrating space at the 1 percent significance level.

The adjustment parameters and their standard deviations are obtained by regressing each of the left hand side variables on calculated deviations from the long run equilibria, lagged left hand side variables and other predetermined variables. Since the same variables enter all the equations, no efficiency is lost by using single equation estimation.

From table 3 we conclude that the cointegrating vectors enter significantly in most of the equations. The only exception is that the real interest rate difference does not enter in the equation for the change in the foreign inflation. The real interest rate difference enters with a significantly negative sign in the equation for the change in the domestic nominal interest rate. This means that if the domestic real interest rate exceeds the foreign one, there will be a negative pressure on the nominal domestic interest rate. Further it is seen that the real interest rate difference enters positively in the equation for the change in the domestic inflation. Thus a higher real interest rate in Norway than abroad goes along with an increase in the domestic inflation rate.

Table 3

Restricted β- and α-vectors in the VAR-model with r = 2. The first cointegration vector is the linear combination corresponding to the RIRP. The second vector is orthogonal to the first. T-values in parentheses.

	α_1	α_2	β_1	β_2
π^d	0.35 (4.6)	0.09 (2.0)	-1	1
π^f	0.15 (1.6)	-0.08 (-2.3)	1	1.93
v	-*)	-*)	0	-0.11
i^d	-0.07 (-3.2)	0.07 (6.0)	1	-3.99
i^f	0.07 (2.5)	0.07 (4.9)	-1	-3.06

* Apriori restriction

7. CONCLUDING REMARKS

In this paper we have investigated five time series within the framework of a VAR model: The domestic inflation rate, the foreign inflation rate, the depreciation of the Norwegian currency, a domestic short-term interest rate and a foreign short-term interest rate. However, we were unable to establish a reasonably well-behaved reduced form model since the residuals in the equation for the change of the depreciation showed signs both of substantial serial correlation and of non-normality. Because of this we had to condition on the depreciation, and thus the dimension of the VAR model was reduced to four. Under this assumption the residuals in the rest of the equations seemed satisfactory. Because we condition on a price freeze dummy and the lagged change in the current account ratio, it is not straightforward to use the simulated distributions by Johansen to make statistical inference about the cointegrating rank. However, we note that there is a substantial decrease in the estimated eigenvalues between the second and the third one. This points to a cointegrating rank of two. However, to study robustness properties we also referred some results where we allowed for a cointegrating rank of three.

In the structural tests we investigated to what extent the linear combinations corresponding to the different parity conditions, outlined in the beginning of this paper, were present in the cointegrating space. These hypotheses were tested under two different values of the cointegration rank, two and three. We conditioned on a price freeze dummy and the lagged change in the current account ratio. Under the "rank equal to two" assumption we found no support of the PPP and the UIP hypotheses. However, some support was found for the RIRP hypothesis. When the cointegrating rank was set to three, the results were somewhat modified. It was not possible to reject the joint hypothesis that both the linear combinations corresponding to the PPP and the UIP were contained in the cointegrating space at the 1 percent significance level. The significance probability connected to the RIRP hypothesis was somewhat reduced. However, it should again be emphasized that the interpretation of these test results is not straightforward since it is based upon the assumption that the depreciation is weakly exogenous with respect to the long-run parameters. This is not an innocent assumption and it is probably not true.

For the model with a cointegrating rank of two, we imposed the RIRP and another cointegrating vector orthogonal to this and calculated the accompanying factor loadings. The two main results from this exercise was that the RIRP entered the equations for the change in the domestic interest rate and the change in the inflation in an intuitively appealing way.

In our empirical analysis we found very weak evidence for the presence of the linear combinations corresponding to the UIP and the PPP. One reason for this may be our rather short sample period. Especially in the case of the PPP hypothesis it is important to have rather long time spans. Several researcher (cf for example Kim (1990)) have reported that it may take several years to restore a deviation from the PPP (in absolute form). However, a longer sample may also involve additional complications in the form of regime shifts and lack of data.

APPENDIX A

We shall now consider the implementation of conditional expectations in the VAR-models described in the introduction.

Assume model (4) and consider $E[Z_{t+1}|\Omega_t] = E[Z_{t+1}|Z_t,Z_{t-1},...]$.

Now $$E[Z_{t+1}|\Omega_t] = \Pi_1 Z_t + ... + \Pi_k Z_{t-k+1} + \Phi D_{t+1} + \mu$$

Consider hypotheses of the form

$$b'E[Z_{t+1}|\Omega_t] = c'Z_t, \tag{A.1}$$

where b and c are px1 fixed vectors.

In our case where p=5, the UIP relation 2 will correspond to $b' = (0,0,1,0,0)$ and $c' = (0,0,0,1,-1)$.

Inserting the expression for $E[Z_{t+1}|\Omega_t]$ means that this is equivalent to

$$\begin{aligned} b'\Pi_1 &= c' \\ b'\Pi_i &= 0 \quad i = 2,...,k \\ b'\Phi &= b'\mu = 0. \end{aligned}$$

Then

$$\begin{aligned} b'(I+\Pi_1+...+\Pi_k-I) &= c' \\ b'\Pi_i &= 0 \quad i = 2,...,k \\ b'\Phi &= b'\mu = 0. \end{aligned}$$

Using the definition of $\Pi = \alpha\beta'$, this means that

$$\begin{aligned} b'\alpha\beta' &= c' - b' \\ b'\Pi_i &= 0 \quad i = 2,...,k \\ b'\Phi' &= b'\mu = 0 \end{aligned}$$

Rearranging we finally end up with the equivalent formulation of (A.1)

(i) $$c - b \in sp(\beta)$$

(ii) $$\begin{aligned} \alpha' b &= (\beta'\beta)^{-1}\beta'(c-b) \\ b'\Pi_i &= 0, \quad i = 2,\dots,k \\ b'\Phi &= b'\mu = 0. \end{aligned}$$

Notice that the condition splits into a condition on the long run coefficients (i), and a condition on the rest of the coefficients (ii).

This means that a test may be conducted in two steps. First a test for the restrictions on the long run parameters along the lines described earlier. Then given a choice of the representation of $\hat{\beta}$, the restrictions of the form (ii) may be carried out as a usual test of restrictions in a stationary time series.

APPENDIX B

Table B1: Single equation statistics in unconstrained models, k = 2

No predetermined variables included

	RSQ	B.P.-Q(9)	ARCH(2)	B-J Normality
Eq. 1	0.761	7.967	1.643	10.491*)
Eq. 2	0.779	11.385	3.812	0.811
Eq. 3	0.552	10.009	0.096	9.011*)
Eq. 4	0.608	24.816*)	0.141	1.136
Eq. 5	0.602	10.863	0.640	1.075

Change in the current account ratio, lagged 2 periods, and a price freeze variable included as predetermined variables

	No variables assumed weakly exogenous				The change in the depreciation assumed to be weakly exogenous			
	RSQ	B.P.-Q(9)	ARCH(2)	B-J Normality	RSQ	B.P.-Q(9)	ARCH(2)	B-J Normality
Eq. 1	0.908	8.312	0.780	0.527*)	0.910	8.800	1.143	0.846
Eq. 2	0.799	11.678	3.324	1.530	0.803	10.089	4.309	2.699
Eq. 3	0.653	17.537*)	0.244	24.700*)	-**)	-**)	-**)	-**)
Eq. 4	0.777	12.700	2.018	0.140	0.802	12.347	0.691	0.131
Eq. 5	0.632	8.978	0.065	0.460	0.637	8.533	0.218	0.154

*) Significant at the 5 percent significance level.
**) The variable is assumed to be weakly exogenous with respect to the long run parameters, and hence the variable is not modelled.

Table B2: Inverses of the roots of the characteristic polynomials of some VAR models*)

r=2			r=3			r=4		
Real	Im	Mod	Real	Im	Mod	Real	Im	Mod
-0.72	0.00	0.72	-0.75	0.00	0.75	0.75	0.00	0.75
-0.34	0.00	0.34	-0.33	0.00	0.33	-0.37	0.00	0.37
0.64	0.00	0.64	1.00	0.00	1.00	0.79	0.18	0.81
0.43	0.14	0.46	0.79	0.17	0.80	0.79	-0.18	0.81
0.43	-0.14	0.46	0.79	-0.17	0.80	0.87	0.00	0.87
0.14	0.00	0.14	0.21	0.16	0.27	0.29	0.11	0.31
1.00	0.00	1.00	0.21	-0.16	0.27	0.29	-0.11	0.31
1.00	0.00	1.00	0.38	0.00	0.38	0.29	0.00	0.29

*) The change in depreciation is assumed to be weakly exogenous with respect to the long run parameters. The price freeze dummy variable and the current account ratio is used as predetermined variables.

APPENDIX C
Residuals and correlograms in the maintained model.

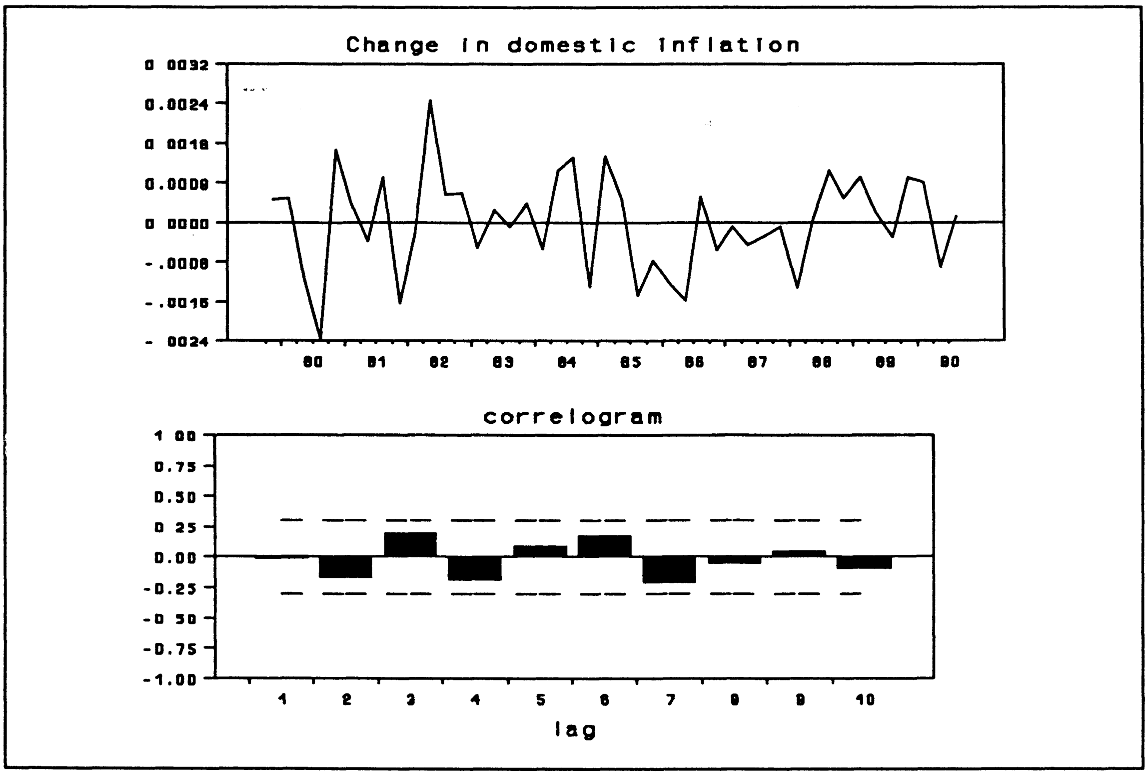

FIGURE C.1: Change in domestic inflation

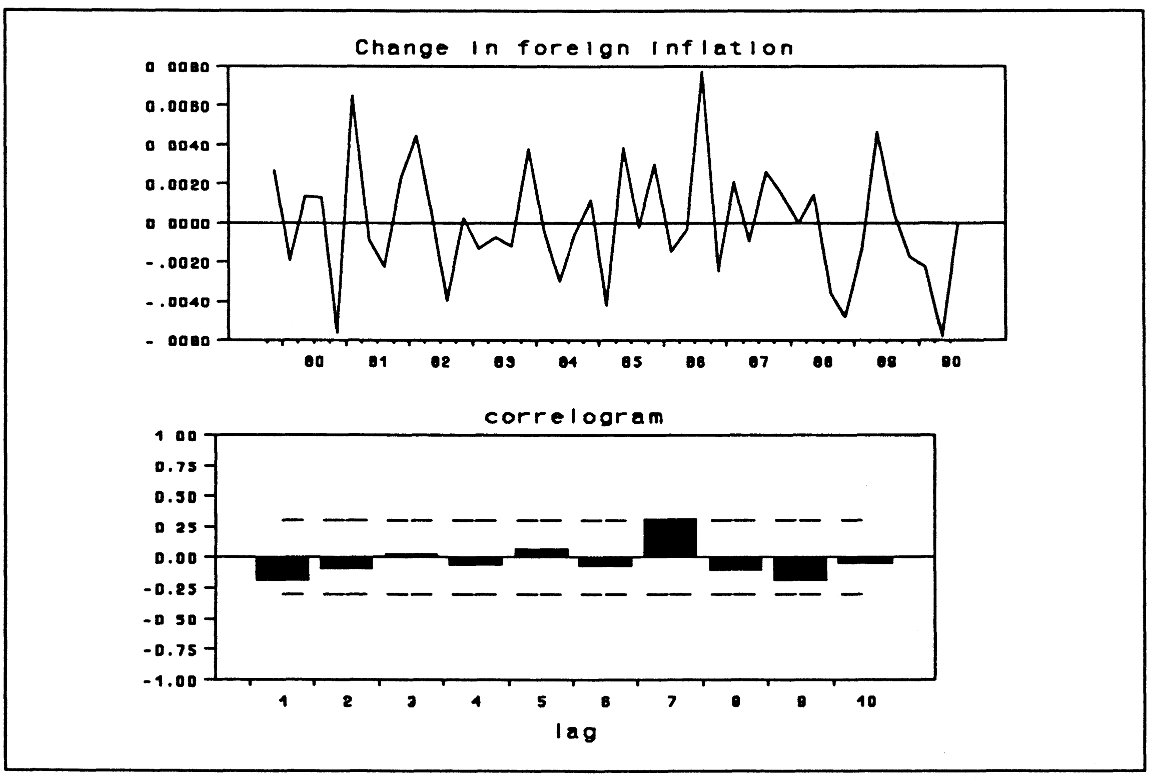

FIGURE C.2: Change in foreign inflation

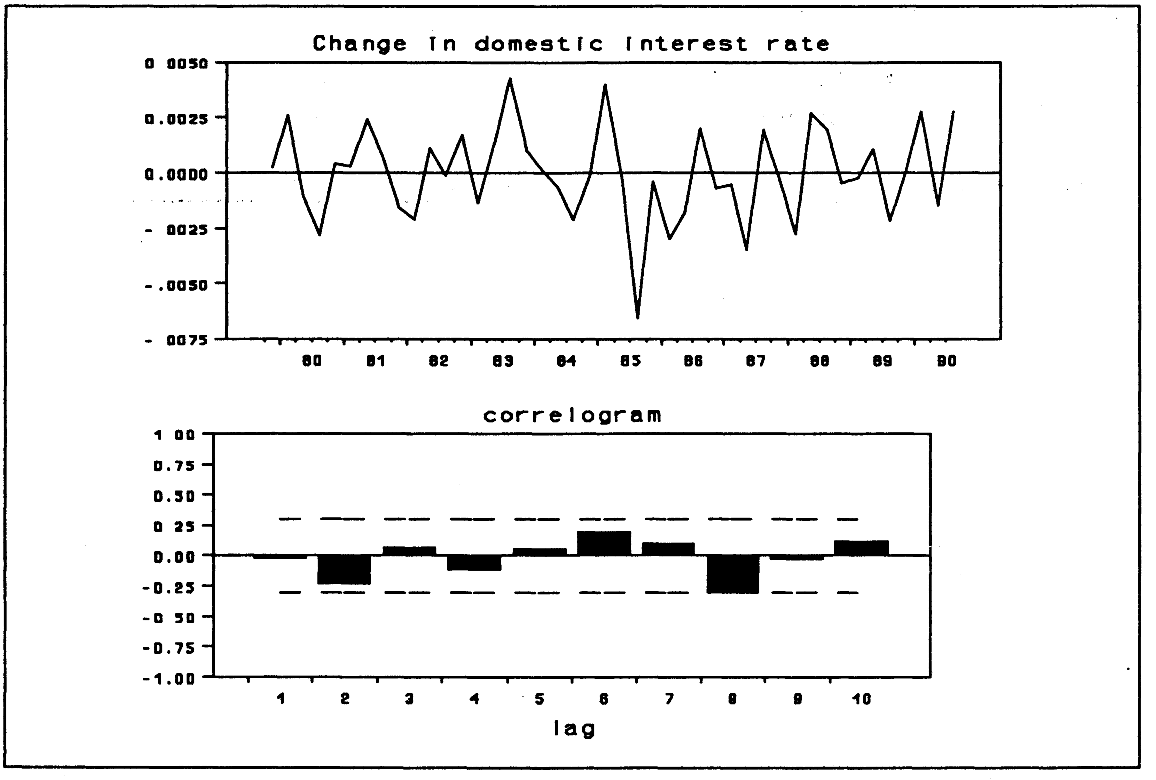

FIGURE C.3: Change in domestic interest rate

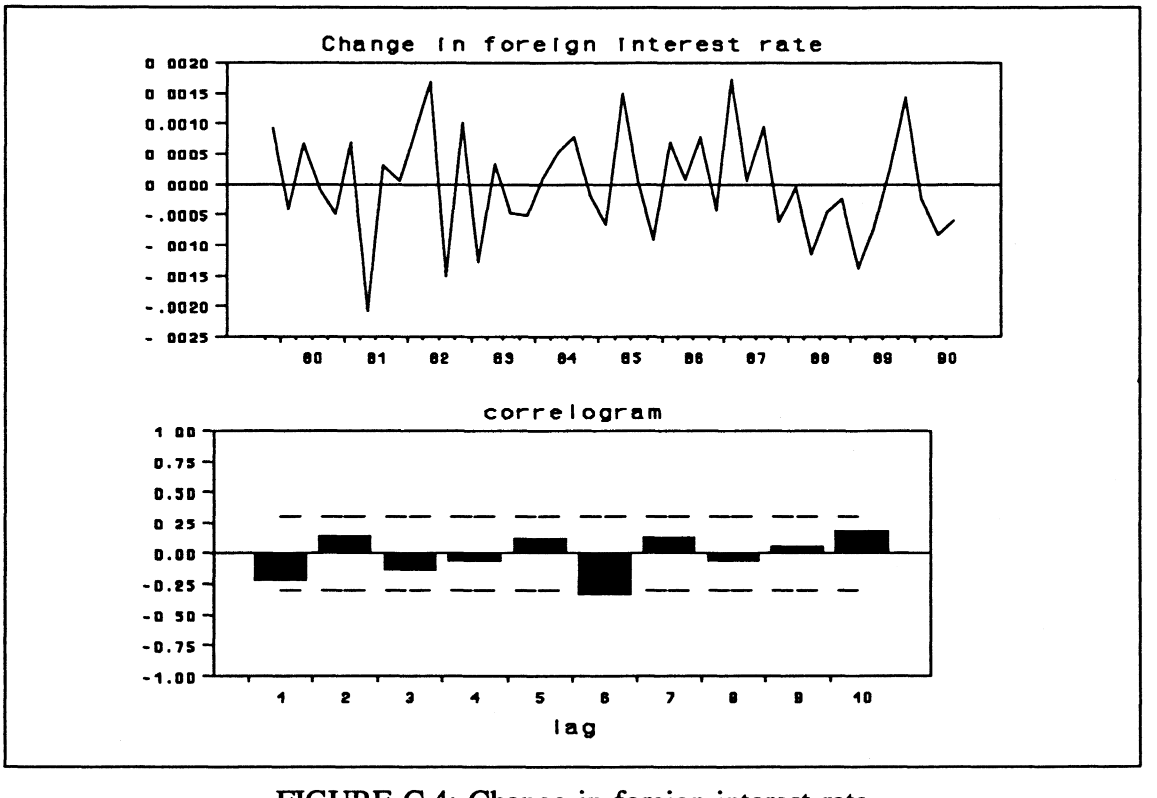

FIGURE C.4: Change in foreign interest rate

References

Adler, Michael and Bruce Lehmann (1983), "Deviations from Purchasing Power Parity in the Long Run", *The Journal of Finance*, Vol XXXVIII, 5, 1471 - 1487.

Baille, Richard T. (1989), "Econometric Tests of Rationality and Market Efficiency", *Econometric Reviews*, 8(2), 151-186.

Baille, Richard T. and Patrick McMahon (1989), *"The foreign exchange market"*, Cambridge University Press 1989.

Edison, Hali J. and Jan Tore Klovland (1987), "A quantitative Reassessment of the Purchasing Power Parity Hypothesis: Evidence from Norway and the United Kingdom", *Journal of Applied Econometrics*, Vol.2, 309 - 333.

Engle, R.F. and C.W.J. Granger (1987), "Co-integration and error correction: Representation, estimation and testing", *Econometrica*, 55, 251 - 276.

Engle, R.F., D. F. Hendry and J.-F. Richard(1983), "Exogeneity", *Econometrica*, 51, 277-304.

Fisher, Eric O'N. and Joon Y. Park (1991), "Testing Purchasing Power Parity under the Null Hypothesis of Co-integration", *The Economic Journal*, 101, 1476 - 1484.

Frenkel, Jacob A. (1978), "Purchasing Power Parity: Doctrinal perspective and evidence from the 1920s", *Journal of International Economics*, 8, 169 - 191.

Hendry, D.F., A.J. Neale and F. Srba (1988), "Econometric Analysis of Small Linear Systems using PC-FIML", *Journal of Econometrics*, 38, 203-226.

Johansen, S. (1991), "Estimation and Hypothesis Testing of Cointegrating Vectors in Gaussian Vector Autoregressive Models", *Econometrica*, 59, 1551-1581.

Johansen, S. (1992a), "A statistical analysis of cointegration for I(2) variables", to appear in *Econometric Theory* (1992).

Johansen, S. (1992b), "Cointegration in partial systems and the efficiency of single-equation analysis", *Journal of Econometrics*, 52, 389-402.

Johansen, S. and K. Juselius (1990), "Maximum Likelihood Estimation and Inference on Cointegration - with Application to the Demand for Money", *Oxford Bulletin of Economics and Statistics*, 52, 169-210.

Johansen, S. and K. Juselius (1992), "Testing structural hypotheses in a multivariate cointegration analysis of the PPP and the UIP for UK", *Journal of Econometrics*, 53, 211 - 244.

Kim, Yoonbai (1990), "Purchasing Power Parity in the Long Run: A cointegration Approach", *Journal of Money, Credit and Banking*, Vol. 22, 4, 491 - 503.

Layton, Allan P. and Jonathan P. Stark (1990), "Co-integration as an Empirical Test of Purchasing Power Parity", *Journal of Macroeconomics*, Vol.12, 1, 125-136.

Patel, Jayendu (1990), "Purchasing Power Parity as a Long-run Relation", *Journal of Applied Econometrics*, Vol. 5, 367 - 379.

Vikøren, B. (1991), "Exchange Rate Expectations and Risk premium: An Empirical Investigation", Working Paper 1991/6 Oslo, Bank of Norway.

ISSUED IN THE SERIES DISCUSSION PAPER

No. 1 *I. Aslaksen and O. Bjerkholt (1985)*: Certainty Equivalence Procedures in the Macroeconomic Planning of an Oil Economy.

No. 3 *E. Biørn (1985)*: On the Prediction of Population Totals from Sample surveys Based on Rotating Panels.

No. 4 *P. Frenger (1985)*: A Short Run Dynamic Equilibrium Model of the Norwegian Production Sectors.

No. 5 *I. Aslaksen and O. Bjerkholt (1985)*: Certainty Equivalence Procedures in Decision-Making under Uncertainty: An Empirical Application.

No. 6 *E. Biørn (1985)*: Depreciation Profiles and the User Cost of Capital.

No. 7 *P. Frenger (1985)*: A Directional Shadow Elasticity of Substitution.

No. 8 *S. Longva, L. Lorentsen and Ø. Olsen (1985)*: The Multi-Sectoral Model MSG-4, Formal Structure and Empirical Characteristics.

No. 9 *J. Fagerberg and G. Sollie (1985)*: The Method of Constant Market Shares Revisited.

No. 10 *E. Biørn (1985)*: Specification of Consumer Demand Models with Stochastic Elements in the Utility Function and the first Order Conditions.

No. 11 *E. Biørn, E. Holmøy and Ø. Olsen (1985)*: Gross and Net Capital, Productivity and the form of the Survival Function. Some Norwegian Evidence.

No. 12 *J.K. Dagsvik (1985)*: Markov Chains Generated by Maximizing Components of Multidimensional Extremal Processes.

No. 13 *E. Biørn, M. Jensen and M. Reymert (1985)*: KVARTS - A Quarterly Model of the Norwegian Economy.

No. 14 *R. Aaberge (1986)*: On the Problem of Measuring Inequality.

No. 15 *A.-M. Jensen and T. Schweder (1986)*: The Engine of Fertility - Influenced by Interbirth Employment.

No. 16 *E. Biørn (1986)*: Energy Price Changes, and Induced Scrapping and Revaluation of Capital - A Putty-Clay Model.

No. 17 *E. Biørn and P. Frenger (1986)*: Expectations, Substitution, and Scrapping in a Putty-Clay Model.

No. 18 *R. Bergan, Å. Cappelen, S. Longva and N.M. Stølen (1986)*: MODAG A - A Medium Term Annual Macroeconomic Model of the Norwegian Economy.

No. 19 *E. Biørn and H. Olsen (1986)*: A Generalized Single Equation Error Correction Model and its Application to Quarterly Data.

No. 20 *K.H. Alfsen, D.A. Hanson and S. Glomsrød (1986)*: Direct and Indirect Effects of reducing SO_2 Emissions: Experimental Calculations of the MSG-4E Model.

No. 21 *J.K. Dagsvik (1987)*: Econometric Analysis of Labor Supply in a Life Cycle Context with Uncertainty.

No. 22 *K.A. Brekke, E. Gjelsvik and B.H. Vatne (1987)*: A Dynamic Supply Side Game Applied to the European Gas Market.

No. 23 *S. Bartlett, J.K. Dagsvik, Ø. Olsen and S. Strøm (1987)*: Fuel Choice and the Demand for Natural Gas in Western European Households.

No. 24 *J.K. Dagsvik and R. Aaberge (1987)*: Stochastic Properties and Functional Forms of Life Cycle Models for Transitions into and out of Employment.

No. 25 *T.J. Klette (1987)*: Taxing or Subsidising an Exporting Industry.

No. 26 *K.J. Berger, O. Bjerkholt and Ø. Olsen (1987)*: What are the Options for non-OPEC Countries.

No. 27 *A. Aaheim (1987)*: Depletion of Large Gas Fields with Thin Oil Layers and Uncertain Stocks.

No. 28 *J.K. Dagsvik (1987)*: A Modification of Heckman's Two Stage Estimation Procedure that is Applicable when the Budget Set is Convex.

No. 29 *K. Berger, Å. Cappelen and I. Svendsen (1988)*: Investment Booms in an Oil Economy -The Norwegian Case.

No. 30 *A. Rygh Swensen (1988)*: Estimating Change in a Proportion by Combining Measurements from a True and a Fallible Classifier.

No. 31 *J.K. Dagsvik (1988)*: The Continuous Generalized Extreme Value Model with Special Reference to Static Models of Labor Supply.

No. 32 *K. Berger, M. Hoel, S. Holden and Ø. Olsen (1988)*: The Oil Market as an Oligopoly.

No. 33 *I.A.K. Anderson, J.K. Dagsvik, S. Strøm and T. Wennemo (1988)*: Non-Convex Budget Set, Hours Restrictions and Labor Supply in Sweden.

No. 34 *E. Holmøy and Ø. Olsen (1988)*: A Note on Myopic Decision Rules in the Neoclassical Theory of Producer Behaviour, 1988.

No. 35 *E. Biørn and H. Olsen (1988)*: Production - Demand Adjustment in Norwegian Manufacturing: A Quarterly Error Correction Model, 1988.

No. 36 *J.K. Dagsvik and S. Strøm (1988)*: A Labor Supply Model for Married Couples with Non-Convex Budget Sets and Latent Rationing, 1988.

No. 37 *T. Skoglund and A. Stokka (1988)*: Problems of Linking Single-Region and Multiregional Economic Models, 1988.

No. 38 *T.J. Klette (1988)*: The Norwegian Aluminium Industry, Electricity prices and Welfare, 1988.

No. 39 *I. Aslaksen, O. Bjerkholt and K.A. Brekke (1988)*: Optimal Sequencing of Hydroelectric and Thermal Power Generation under Energy Price Uncertainty and Demand Fluctuations, 1988.

No. 40 *O. Bjerkholt and K.A. Brekke (1988)*: Optimal Starting and Stopping Rules for Resource Depletion when Price is Exogenous and Stochastic, 1988.

No. 41 *J. Aasness, E. Biørn and T. Skjerpen (1988)*: Engel Functions, Panel Data and Latent Variables, 1988.

No. 42 *R. Aaberge, Ø. Kravdal and T. Wennemo (1989)*: Unobserved Heterogeneity in Models of Marriage Dissolution, 1989.

No. 43 *K.A. Mork, H.T. Mysen and Ø. Olsen (1989)*: Business Cycles and Oil Price Fluctuations: Some evidence for six OECD countries. 1989.

No. 44 *B. Bye, T. Bye and L. Lorentsen (1989)*: SIMEN. Studies of Industry, Environment and Energy towards 2000, 1989.

No. 45 *O. Bjerkholt, E. Gjelsvik and Ø. Olsen (1989)*: Gas Trade and Demand in Northwest Europe: Regulation, Bargaining and Competition.

No. 46 *L.S. Stambøl and K.Ø. Sørensen (1989)*: Migration Analysis and Regional Population Projections, 1989.

No. 47 *V. Christiansen (1990)*: A Note on the Short Run Versus Long Run Welfare Gain from a Tax Reform, 1990.

No. 48 *S. Glomsrød, H. Vennemo and T. Johnsen (1990)*: Stabilization of Emissions of CO_2: A Computable General Equilibrium Assessment, 1990.

No. 49 *J. Aasness (1990)*: Properties of Demand Functions for Linear Consumption Aggregates, 1990.

No. 50 *J.G. de Leon (1990)*: Empirical EDA Models to Fit and Project Time Series of Age-Specific Mortality Rates, 1990.

No. 51 *J.G. de Leon (1990)*: Recent Developments in Parity Progression Intensities in Norway. An Analysis Based on Population Register Data.

No. 52 *R. Aaberge and T. Wennemo (1990)*: Non-Stationary Inflow and Duration of Unemployment.

No. 53 *R. Aaberge, J.K. Dagsvik and S. Strøm (1990)*: Labor Supply, Income Distribution and Excess Burden of Personal Income Taxation in Sweden.

No. 54 *R. Aaberge, J.K. Dagsvik and S. Strøm (1990)*: Labor Supply, Income Distribution and Excess Burden of Personal Income Taxation in Norway.

No. 55 *H. Vennemo (1990)*: Optimal Taxation in Applied General Equilibrium Models Adopting the Armington Assumption.

No. 56 *N.M. Stølen (1990)*: Is there a NAIRU in Norway?

No. 57 *Å. Cappelen (1991)*: Macroeconomic Modelling: The Norwegian Experience.

No. 58 *J. Dagsvik and R. Aaberge (1991)*: Household Production, Consumption and Time Allocation in Peru.

No. 59 *R. Aaberge and J. Dagsvik (1991)*: Inequality in Distribution of Hours of Work and Consumption in Peru.

No. 60 *T.J. Klette (1991)*: On the Importance of R&D and Ownership for Productivity Growth. Evidence from Norwegian Micro-Data 1976-85.

No. 61 *K.H. Alfsen (1991)*: Use of Macroeconomic Models in Analysis of Environmental Problems in Norway and Consequences for Environmental Statistics.

No. 62 *H. Vennemo (1991)*: An Applied General Equilibrium Assessment of the Marginal Cost of Public Funds in Norway.

No. 63 *H. Vennemo (1991)*: The Marginal Cost of Public Funds: A Comment on the Literature.

No. 64 *A. Brendemoen and H. Vennemo (1991)*: A climate convention and the Norwegian economy: A CGE assessment.

No. 65 *K. A. Brekke (1991)*: Net National Product as a Welfare Indicator.

No. 66 *E. Bowitz and E. Storm (1991)*: Will Restrictive Demand Policy Improve Public Sector Balance?

No. 67 *Å. Cappelen (1991)*: MODAG. A Medium Term Macroeconomic Model of the Norwegian Economy.

No. 68 *B. Bye (1992)*: Modelling Consumers' Energy Demand.

No. 69 *K. H. Alfsen, A. Brendemoen and S. Glomsrød (1992)*: Benefits of Climate Policies: Some Tentative Calculations.

No. 70 *R. Aaberge, Xiaojie Chen, Jing Li and Xuezeng Li (1992)*: The Structure of Economic Inequality among Households Living in Urban Sichuan and Liaoning, 1990.

No. 71 *K.H. Alfsen, K.A. Brekke, F. Brunvoll, H. Lurås, K. Nyborg and H.W. Sæbø (1992)*: Environmental Indicators.

No. 72 *B. Bye and E. Holmøy (1992)*: Dynamic Equilibrium Adjustments to a Terms of Trade Disturbance

No. 73 *O. Aukrust (1992):* The Scandinavian Contribution to National Accounting

No. 74 *J. Aasness, E, Eide and T. Skjerpen (1992):* A Criminometric Study Using Panel Data and Latent Variables

No. 75 *R. Aaberge and Xuezeng Li (1992):* The Trend in Income Inequality in Urban Sichuan and Liaoning, 1986-1990

No. 76 *J.K. Dagsvik and Steinar Strøm (1992):* Labor Supply with Non-convex Budget Sets, Hours Restriction and Non-pecuniary Job-attributes

No. 77 *J.K. Dagsvik (1992)*: Intertemporal Discrete Choice, Random Tastes and Functional Form

No. 78 *H. Vennemo (1993)*: Tax Reforms when Utility is Composed of Additive Functions.

No. 79 *J. K. Dagsvik (1993):* Discrete and Continuous Choice, Max-stable Processes and Independence from Irrelevant Attributes.

No. 80 *J. K. Dagsvik (1993):* How Large is the Class of Generalized Extreme Value Random Utility Models?

No. 81 *H. Birkelund, E. Gjelsvik, M. Aaserud (1993):* Carbon/energy Taxes and the Energy Market in Western Europe

No. 82 *E. Bowitz (1993):* Unemployment and the Growth in the Number of Recipients of Disability Benefits in Norway

No. 83 *L. Andreassen (1993):* Theoretical and Econometric Modeling of Disequilibrium

No. 84 *K.A. Brekke (1993):* Do Cost-Benefit Analyses favour Environmentalists?

No. 85 *L. Andreassen (1993):* Demographic Forecasting with a Dynamic Stochastic Microsimulation Model

No. 86 *G.B. Asheim and K.A. Brekke (1993):* Sustainability when Resource Management has Stochastic Consequences

No. 87 *O. Bjerkholt and Yu Zhu (1993):* Living Conditions of Urban Chinese Households around 1990

No. 88 *R. Aaberge (1993):* Theoretical Foundations of Lorenz Curve Orderings

No. 89 *J. Aasness, E. Biørn and T. Skjerpen (1993):* Engel Functions, Panel Data, and Latent Variables - with Detailed Results

No. 90 *Ingvild Svendsen (1993):* Testing the REH. Using Norwegian Microeconomic Data (Will be issued later)

No. 91 *Einar Bowitz, Asbjørn Rødseth and Erik Storm (1993):* Fiscal Expansion, the Budget Deficit and the Economy: Norway 1988-91

No. 92 *Rolf Aaberge, Ugo Colombino and Steinar Strøm (1993):* Labor Supply in Italy

No. 93 *Tor Jakob Klette (1993):* Is Price Equal to Marginal Costs? An Integrated Study of Price-Cost Margins and Scale Economies among Norwegian Manufacturing Establishments 1975-90.

No. 94 *John K. Dagsvik (1993):* Choice Probabilities and Equilibrium Conditions in a Matching Market with Flexible Contracts

No. 95 *Tom Kornstad (1993):* Empirical Approaches for Analysing Consumption and Labour Supply in a Life Cycle Perspective

No. 96 *Tom Kornstad (1993):* An Empirical Life Cycle Model of Savings, Labour Supply and Consumption without Intertemporal Separability

No. 97 *Snorre Kverndokk (1993):* Coalitions and Side Payments in International CO_2 Treaties

No. 98 *Torbjørn Eika (1993):* Wage Equations in Macro Models. Phillips Curve versus Error Correction Model Determination of Wages in Large-Scale UK Macro Models

No. 99 *Anne Brendemoen and Haakon Vennemo (1993):* The Marginal Cost of Funds in the Presence of External Effects

No. 100 *Kjersti-Gro Lindquist (1993):* Empirical Modelling of Norwegian Exports: A Disaggregated Approach

No. 101 *Anne Sofie Jore, Terje Skjerpen and Anders Rygh Swensen (1993):* Testing for Purchasing Power Parity and Interest Rate Parities on Norwegian Data

Macroeconomic Division, P.B. 8131 Dep, 0033 Oslo, Norway
Tel: (47) 22 86 48 32,
Fax: (47) 22 11 12 38, Telex: 11 202 SSB N