TESTING FOR AUTOCORRELATION AND MODEL SPECIFICATION WITH THE IAS-SYSTEM

(Final Report)*)

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Contents

1. Introduction

Recent years have witnessed a remarkable growth of interest in testing the assumptions underlying the econometric model building and estimation process. The present paper summarizes our effort to incorporate these ideas into the IAS-SYSTEM.

The IAS-SYSTEM is a dialog-oriented computer software package for econometric modelling and corporate planning. It is being developped since the mid 70's in the department of mathematics and computer science at the Vienna Institute for Advanced Studies, in close cooperation with the Institute's economics department and external users. The main features of the IAS-SYSTEM are easy data handling and manipulation and the simulation of (possibly nonlinear) econometric models comprising several hundred equations. In addition, the IAS-SYSTEM provides all standard econometric estimation procedures, linear programming and seasonal adjustment techniques, and a broad selection of time series methods such as power spectra and procedures for the estimation and forecasting of ARMA-models.

This paper gives an overview of econometric tests and diagnostic checking techniques that have recently been added to the System. Among the procedures now available are tests for higher order serial correlation in the context of lagged endogenous variables and simultaneous equations, and tests to detect nonlinearity, structural breaks and errors in the variables. The particular selection of procedures reflects the needs of users of the IAS-SYSTEM, and is not intended to be representative of ongoing research on testing econometric hypotheses.

Section 2 below presents the theoretical framework of the tests. This is meant to give a rough idea of the procedures rather than to provide a substitute for the original literature. For more detailed surveys, see Hausman (1978), Judge et al. (1980), Breusch and Pagan (1980), King (1983) or Engle (1982). Some problems associated with the implementation of various tests are also discussed in Havlik and Sonnberger (1983) and Maurer (1983). For a comprehensive userguide, see Maurer et al. (1983). Since the material surveyed is rather heterogenous, we do not suggest a unique testing strategy to guide the user in empirical applications. Some hints on how to proceed in practice may be taken from the examples that are discussed in Section 3, however. A particular strategy to discriminate between autocorrelation and misspecification is found in Thursby (1981), and the complications that arise when various departures from the model assumptions occur at the same time are discussed in Epps and Epps (1977) and Thursby (1983).

Following the survey of the tests, Section 3 exemplifies in some details how they might be used in empirical applications. The data and some relevant statistical tables are reproduced in the appendix.

2. Review of Relevant Econometric Literature

The point of departure of much of what follows is the standard linear regression model

(2-1) $$y_t = x_t^{'}\beta + u_t \ , \qquad t=1,\ldots,T$$

or, in matrix notation

(2-2) $$y = X\beta + u \ ,$$

where X is a nonstochastic TxK matrix of independent variables, β is the Kx1 vector of regression parameters, and u is a Tx1 disturbance vector with $u \sim N(0,\sigma^2 I)$. $\hat{\beta}=(X'X)^{-1}X'y$ denotes the OLS-estimate of β, $\hat{u}=y-X\hat{\beta}$ is the corresponding vector of residuals, and $s^2=\hat{u}'\hat{u}/(T-K)$ is the OLS-estimate of σ^2. Allmost all of the tests to be discussed in the sequel are supposed to detect various deviations from the assumptions underlying (1) and (2).

a) Autocorrelated disturbances

The most commonly used procedure to test for correlation among disturbances is still the Durbin-Watson test, based on the statistic

(2-3) $$d_1 = \frac{\sum_{t=2}^{T} (\hat{u}_t-\hat{u}_{t-1})^2}{\sum_{t=1}^{T} \hat{u}_t^2}$$

However, since d_1 is specifically designed to test for AR(1) errors, it might have poor power when the disturbances are generated by a different scheme. Wallis (1972) has suggested that a AR(4) error process $u_t=\rho u_{t-4}+\varepsilon_t$ might be a more reasonable alternative when quarterly data are used, leading to the test statistic

$$(2\text{-}4) \qquad d_4 = \frac{\sum_{t=5}^{T} (\hat{u}_t-\hat{u}_{t-4})^2}{\sum_{t=1}^{T} \hat{u}_t^2} \; .$$

Like the Durbin-Watson test, the procedure based on d_4 is a bounds test, with analogous rules to accept or reject the null hypothesis $H_o: u \sim N(0,\sigma^2 I)$. A table of bounds for 5 % significance points is reproduced in the appendix. The test shares the familiar optimality properties of the Durbin-Watson test when the errors are indeed AR(4).

A further test and the relevant bounds is given by Schmidt (1972). For testing the null hypothesis $H_o: \rho_1= \rho_2=0$, when the alternative is $u_t=\rho_1 u_{t-1}+\rho_2 u_{t-2}+\varepsilon_t$, he suggests using d_1+d_2 .

There has been some work recently on narrowing the bounds for the Durbin-Watson significance points when additional information on X is available (Krämer, 1971; Giles and King, 1978; Farebrother, 1980 ; King, 1981) and on extending the respective tables for extreme sample sizes (Savin and White, 1977). A selection of these tables is reproduced in the appendix. There also exist algorithms to compute exact significance points for any given X (Imhof, 1961; Pan Jei-jian, 1968).

Breusch and Pagan (1980) point out that the j'th estimated autocorrelation coefficient

$$(2\text{-}5) \qquad r_j = \frac{\Sigma_{t=j+1}^{T} \hat{u}_t \hat{u}_{t-j}}{\Sigma_{t=1}^{T} \hat{u}_t^2}$$

may be used to test against $H_1 : u_t = \rho_j u_{t-j} + \varepsilon_t$; $\sqrt{T}\, r_j$ is the LM-statistic for $H_o : \rho_j = 0$. It is standard normal asymptotically, provided there are no lagged endogenous variables.

Almost all of the above procedures may give misleading results when there are lagged endogenous variables among the regressors (see for instance Nerlove and Wallis (1966) for a discussion of the adverse effects of lagged endogenous variables on the size and the power of the Durbin-Watson test). For the AR(1) alternative, Durbin (1970) suggests correcting $\sqrt{T}\, r_1$ for the effect of lagged endogenous variables, which leads to the test statistic

$$(2\text{-}6) \qquad h_1 = \sqrt{\frac{T}{1 - T\hat{V}(\beta_1)}} \cdot r_1 \quad ,$$

where $\hat{V}(\beta_1)$ is the OLS-estimate of the variance of coefficient of y_{t-1}, β_1. Under the null hypothesis of no serial correlation, h_1 is asymptotically normal with zero mean and unit variance. This also holds when X contains lags of y exceeding one.

Godfrey and Tremayne (1978) suggest an analoguous test for AR(4) alternatives that is based on the statistic

$$(2\text{-}7) \qquad h_4 = (1-\frac{1}{2}\, d_4)\sqrt{\frac{T}{1-T\tau'\hat{V}(\beta)\tau}}\quad ,$$

where d_4 is from (4) and $\hat{V}(\beta)=s^2(X'X)^{-1}$ is the covariance matrix of $\hat{\beta}$ as estimated by OLS. τ is a vector depending on the maximum lag m of the endogenous variable. For

$$\begin{aligned}
m=1 &: \tau' = (\hat{\beta}_1^3,0,\dots,0)\\
m=2 &: \tau' = (\hat{\beta}_1^3+2\hat{\beta}_1\hat{\beta}_2,\hat{\beta}_1^2+\hat{\beta}_2,0,\dots,0)\\
m=3 &: \tau' = (\hat{\beta}_1^3+2\hat{\beta}_1\hat{\beta}_2+\hat{\beta}_3,\hat{\beta}_1^2+\hat{\beta}_2,\hat{\beta}_1,0,\dots,0)\\
m>3 &: \tau' = (\hat{\beta}_1^3+2\hat{\beta}_1\hat{\beta}_2+\hat{\beta}_3,\hat{\beta}_1^2+\hat{\beta}_2,\hat{\beta}_1,1,0\dots,0) \quad .
\end{aligned}$$

h_4 is asymptotically N(0,1) under H_o. Note that h_1 and h_4 cannot be computed for $T\hat{V}(\beta_1)$ or $T\tau'\hat{V}(\beta)\tau$ greater than unity.

Similar to the procedures based on unadjusted empirical correlations of OLS-residuals, the h-test can be derived from the LM-principle, as has been observed by a number of authors (Aldrich, 1978; Breusch, 1978; Godfrey, 1978b). The r_j's adjusted for the effects of lagged endogenous variables, $r_j^{(e)}$ (j=1,2,...), such that $r_j^{(e)}\sim N(0,1)$ under H_o, can likewise be obtained through the LM-approach. However, like the r_j's, they can only be used to test against very special alternatives ($\rho_j\neq 0$ for given j; $\rho_i=0$, $i\neq j$). Godfrey (1978a) therefore suggests a test for the existence of AR or MA disturbances of any order, where the ρ_i (i=1,...,j-1) need not be zero, which in addition is asymptotically valid whether or not X contains lagged values of the endogenous variable. For both an MA(q) and AR(q) alternative, the statistic is

$$(2\text{-}8) \qquad l = T \cdot \frac{\hat{u}'\hat{U}[\hat{U}'\hat{U}-\hat{U}'X(X'X)^{-1}X'\hat{U}]^{-1}\hat{U}'\hat{u}}{\hat{u}'\hat{u}}$$

where $\hat{U} = [\hat{u}^{(1)},\hat{u}^{(2)},\ldots,\hat{u}^{(q)}]$,

$$\hat{u}^{(i)} = (0,\ldots,0,\hat{u}_1,\ldots,\hat{u}_{T-i})' , \; i=1,\ldots,q \; ,$$

and l has an asymptotic $\chi^2_{(q)}$ distribution under the null hypothesis of no correlation. Significantly large values of l imply that the assumption that the errors are serially independent is not consistent with the sample data.

The l-test is derived through the Lagrange Multiplier (LM) approach and is therefore asymptotically equivalent (in the sense that the difference between the respective test statistics tends to zero both under the null hypothesis and a sequence of local alternatives) to the LR test, but requires only estimation under H_o. The test statistic is easily seen to be equal to TR^2 in a regression of $\hat{u}$ against $[\hat{u}^{(1)},\ldots,\hat{u}^{(q)}, X]$.

The IAS-SYSTEM now also offers a test for serial correlation of the errors in a simultaneous equation context. Consider a linear simultaneous equation system

$$(2\text{-}9) \qquad YB + Z\Gamma = U$$

where Y is a TxG matrix of observations on endogenous variables, Z is a TxK matrix of observations on exogenous variables, and U is a TxG matrix of structural disturbances.

B and Γ are respectively GxG and KxG matrices of structural coefficients. Write the equation of interest as

$$(2\text{-}10) \qquad y_1 = Y_2\beta + Z_1\gamma + u_1 \quad ,$$

where y_1 and Y_2 are, respectively, a Tx1 and Txg_1 matrix of observations on g_1+1 endogenous variables and Z_1 is a Txk_1 matrix of observations on k_1 exogenous variables. Denote the 2SLS-estimate for β by β^*. Harvey and Phillips (1980) show that, under the null hypothesis of no serial correlation, the Durbin-Watson statistic d_1 computed from the OLS-regression of $y_1-Y_2\beta^*$ against Z has the same distribution as in the standard single equation context, with parameters T and K. It can therefore be used as a bounds test for serial correlation in the same manner as in ordinary regression. However, it should be warned that this procedure is only valid when there are no lagged endogenous variables among the predetermined variables of the system.

b) Heteroscedastic and nonnormal disturbances

The standard procedure to test for heteroscedastic disturbances is the Goldfeld-Quandt test (see Goldfeld and Quandt 1965). It depends on one's ability to rank the observations according to increasing variance. The IAS-SYSTEM offers two criteria for reordering the sample: (i) time (the default value) and (ii) the absolute values of a user-specified exogenous variable. The Goldfeld-Quandt test is then based on running two separate regressions, on the first and the last (T-r)/2 observations, where r central observations are omitted. The test statistic is

$$(2.11) \qquad R = \frac{\hat{u}_1' \ \hat{u}_1}{\hat{u}_2' \ \hat{u}_2}$$

where $\hat{u}_i$ is the vector of residuals of the i'th regression (i=1,2). Under H_o, R has an F-distribution with $[(T-r-2K)/2, \ (T-r-2K)/2]$ degrees of freedom.

For the general class of heteroscedastic error structures given by

$$(2\text{-}12) \qquad E(u_t^2) = h(z_t'\alpha) \quad ,$$

where h is a function independent of t and z_t is a px1-vector of nonstochastic variables (the first of which is assumed to be unity) that may or may not be identical to the independent variables of the regression, Breusch and Pagan (1979) suggest the following test of $H_o : \alpha_2 = \ldots = \alpha_p = 0$: Regress $\hat{u}_t^2/s^2$ against z_t and reject H_o if

$$(2\text{-}13) \qquad LM = \sum_{t=1}^{T} \hat{z}_t^2 = \Sigma_{t=1}^{T} (z_t \hat{a})^2$$

is too large. LM is distributed asymptotically as $\chi^2_{(p-1)}$ and results from a Lagrange Multiplier approach. Note that H_o is equivalent to $u \sim N(0,\sigma^2 I)$.

The test statistic above is identical to that given by Godfrey (1978c) for testing against the more specific alternative $E(u_t^2) = \exp(z_t'\alpha)$ (i.e. the log of the variance of y_t is a linear function of certain exogenous variables). However, from Breusch and Pagan (1979) it is clear that this statistic is justified for a much wider class of alternatives. Both Godfrey and Breusch and Pagan found that, in finite samples the test rejects the null hypothesis when it is true less frequently than indicated by the selected type I error and that it is quite powerful when heteroscedasticity is actually present. A similar test against this type of alternative was suggested by Harvey (1976).

The IAS-SYSTEM now also routinely calculates heteroscedasticity-adjusted t-values as suggested by White (1980). It is well known that the conventional t-value of a regression-coefficient β_i,

$$(2\text{-}14) \qquad t_i = \frac{\hat{\beta}_i}{\sqrt{s^2 d_i}} ,$$

where d_i is the i'th diagonal element of $(X'X)^{-1}$, need no longer have a t-distribution when errors are heteroscedastic. This is so because $s^2 d_i$ does no longer provide an unbiased estimate of the variance of $\hat{\beta}_i$, and can easily lead to wrong inferences when heteroscedasticity among errors is present. White suggests using

$$(2\text{-}15) \qquad (X'X)^{-1} \left[\sum_{t=1}^{T} \hat{u}_t^2 \, x_t x_t' \right] (X'X)^{-1}$$

rather than $s^2(X'X)^{-1}$ to estimate $\mathrm{cov}(\hat{\beta})$, proving under rather mild regularity conditions that (15) consistently estimates $\lim_{T\to\infty} T \, \mathrm{cov}(\hat{\beta})$ irrespective of any heteroscedasticity. Thus, plugging in the i'th diagonal element of (15) into (14) in place of $s^2 d_i$ gives a statistic which is asymptotically distributed as t even when errors are heteroscedastic.

Nicholls and Pagan (1983) extend White's result to models with lagged endogenous variables.

White's approach leads naturally to a direct test for heteroscedasticity, by comparing the adjusted and unadjusted estimates of $\mathrm{cov}(\hat{\beta})$. These should be close to each other under the null hypothesis of homoscedastic errors. The resulting test statistic is asymptotically equivalent to T times R^2 from a regression of the squared OLS-residuals on all second order products and cross products of the original regressors and is asymptotically distributed as $\chi^2_{K(K+1)/2}$ under H_o. This test may also serve as a general test for model misspecification in the sense that failure of other model assumptions (i.e. linearity) may also lead to a statistically significant test statistic.

Since this test does not require specifying the (possible) heteroscedastic structure of the errors, it might have less power than other tests when the particular alternative assumed is indeed true. On the other hand, it is difficult enough to specify the regression part of the model, about which there is generally some guidance, without being required to state exactly how the error variances change, which makes White's approach attractive for applications where no particular form for the heteroscedasticity suggests itself.

Since most tests discussed so far assume errors to be normal, it also seems worthwile considering how one could test to see if this assumption is indeed justified. Among the large number of possible tests for normality that have been suggested in the literature, (see, for example, the recent papers by *Pearson*, *D'Agostino* and *Bowman* (1977), *Gastwirth* and *Owens* (1977), *Locke* and *Spurrier* (1977), *Spiegelhalter* (1977) or *McDonald* and *White* (1980)), a procedure suggested by *Jarque* and *Bera* (1980) has been selected for the IAS-SYSTEM. It is based on measures of skewness and kurtosis of the OLS-residuals, leading to the test-statistic

$$(2\text{-}16) \qquad N = T \cdot \frac{\frac{1}{6}\frac{(\frac{1}{T}\Sigma\hat{u}_t^3)^2}{(\frac{1}{T}\Sigma\hat{u}_t^2)^3} + \frac{1}{24}\left[\frac{\frac{1}{T}\Sigma\hat{u}_t^4}{(\frac{1}{T}\Sigma\hat{u}_t^2)^2} - 3\right]^2}{\frac{3}{2}\left[\frac{(\frac{1}{T}\Sigma\hat{u}_t)^2}{\frac{1}{T}\Sigma\hat{u}_t^2} - \frac{(\frac{1}{T}\Sigma\hat{u}_t^3)(\frac{1}{T}\Sigma\hat{u}_t)}{(\frac{1}{T}\Sigma\hat{u}_t^2)^2}\right]} \; .$$

N is asymptotically distributed as $\chi^2_{(2)}$ under H_o: $u \sim N(O, \sigma^2 I)$, with N large indicating that the null hypothesis should be rejected.

c) Structural breaks and nonlinearity in the variables

Quandt (1958, 1960) has suggested the following test statistic when it is believed that the regression relationship may have changed at a time point t=r from one relationship given by β_1, σ_1^2 to another relationship specified by β_2, σ_2^2:

$$(2.17) \qquad \lambda_r = \log \left(\frac{\text{max likelihood given } H_o}{\text{max likelihood given } H_1} \right)$$

$$= \frac{1}{2} r \log s_1^2 + \frac{1}{2}(T-r) \log s_2^2 - \frac{1}{2} T \log s^2$$

where s_1^2 and s_2^2 are the residual sums of squares, divided by the number of observations, in the separate regressions, and H_1 is the hypothesis that the observations in the time segments $(1,\ldots,r)$ and $(r+1,\ldots,T)$ come from two different regressions. λ_r is the standard likelihood ratio statistic for this problem. The IAS-SYSTEM computes and plots λ_r for each r=K+1 to T-K-1. If r is unknown, an estimate of the point at which the switch from one relationship to the other has occured is then provided by the value of r at which λ_r attains its minimum.

For the case where r is known, and the only question is as to whether β is constant, Chow (1960) has suggested the following test: Fit both

$$(2.18) \qquad y_1 = X_1\beta_1 + u_1 \ ; \ y_2 = X_2\beta_2 + u_2$$

and reject H_o whenever

$$(2\text{-}19) \qquad F = \frac{(\hat{u}'\hat{u}-\tilde{u}'\tilde{u})/K}{\tilde{u}'\tilde{u}/(T-2K)}$$

is too large, where $\tilde{u}=[\hat{u}_1' \ , \ \hat{u}_2']$ is the vector of OLS residuals obtained from fitting both parts of (18) seperately (Assuming $K< r$ and $K<T-r$).This is intuitively reasonable, since large values of F mean that the OLS fit is greatly increased by breaking up the regression. The exact rejection region is determined by noting that under H_o F has an F distribution with K and T-2K degrees of freedom.

It is easily seen that the Chow test is a special case of the F-test of the general hypothesis H_o:$A\beta=a$ in the model

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} X_1 & 0 \\ 0 & X_2 \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \end{bmatrix} + \begin{bmatrix} u_1 \\ u_2 \end{bmatrix} ,$$

where $A = [I \vdots -I]$, $\beta = \begin{bmatrix} \beta_1 \\ \beta_2 \end{bmatrix}$ and $a=0$, and could thus be computed by hand using the general F-test that is now also available in the IAS-SYSTEM.

The relationship between various types of F-tests is very well explained in Dhrymes (1978, chapter 2).

One major drawback of the Chow test is that the point in time where the structural break might possibly occur must be known. Alternative techniques for detecting departures from constancy of regression relationships over time, where such prior knowledge is not required, have been suggested by Brown, Durbin and Evans (1975).

The CUSUM-test is based on cumulative sums of recursive residuals. Let $\hat{\beta}_r$ $(r \geq K)$ be the OLS-estimate of β based on the first r observations, i.e. $\hat{\beta}_r = (X_r^{'}X_r)^{-1} X_r' y_r$, where $X_r'X_r$ is assumed to be non-singular, and let

$$(2\text{-}20) \qquad w_r = \frac{y_r - x_r'\hat{\beta}_{r-1}}{(1+x_r'(X_{r-1}'X_{r-1})^{-1}x_r)^{1/2}} \ , \ r=K+1,\dots,T \ .$$

Brown et al. (1975) show that $w_{K+1},\dots,w_T$ are independent $N(0,\sigma^2)$ under H_o: β constant for all t and $u \sim N(0,\sigma^2 I)$. The transformation from the u_t's to the w_r's may be shown to be a generalized form of the well known Helmert transformation (Kendall and Stuart, 1969, p. 250).

If β is constant up to time $t=t_o$ and differs from this constant value from then on, the w_r's will have zero means for r up to t_o but in general will not have zero means subsequently. It therefore seems reasonable to expect some information on possible structural breaks from a plot of the cusum quantity

$$(2\text{-}21) \qquad w_r = \frac{1}{S} \sum_{j=k+1}^{r} w_j$$

against r for $r=K+1,\ldots,T$, where S denotes the estimated standard deviation determined by $S=(\frac{1}{T-K} \Sigma \hat{u}_t^2)^{1/2}$. The CUSUM-technique of testing the significance of the departure of the sample path of w_r from its mean value line $E(w_r)=0$ is to find a pair of lines lying symmetrically above and below the line $w_r=0$ such that the probability of crossing one or both lines equals the required significance level α.

Brown et al. propose straight lines through the points $(K, \pm a\sqrt{T-K})$, $(T, \pm 3a\sqrt{T-K})$, where a depends on α. Useful pairs of values of a and α are

$\alpha = 0.01$	$a = 1.143$
$\alpha = 0.05$	$a = 0.948$
$\alpha = 0.10$	$a = 0.850$.

In practice, one frequently has a regression model with a constant, where in addition one or more of the regressors are dummies and themselves constant for the first r_1 observations, $(r_1 \geq K)$. The recursive residuals can then not be computed from (20) because of multicollinearity, but the IAS-SYSTEM takes charge of that by initially dropping the dummy and reducing the number of regressors to K-1. When the dummy has changed it is brought into the regression and recursive residuals are calculated from then on by (20).

For the statistical implication of this procedure, see Brown et al. (1975, p. 153). Things can become more complicated when there is more than one dummy with constant values for the initial observations. The IAS-SYSTEM can handle a maximum of 2. For details, see Maurer (1983).

Also available in the IAS-SYSTEM is the CUSUM of Squares test, which is based on the plot of the quantities

$$(2\text{-}22) \qquad S_r = \frac{\sum_{j=K+1}^{r} w_j^2}{\sum_{j=K+1}^{T} w_j^2} \quad , \qquad r = K+1,\ldots,T \quad .$$

Under H_o, S_r has a beta distribution with mean (r-K)/(T-K). Therefore it seems intuitively reasonable to reject H_o whenever S_r crosses one of the lines $f_r=\pm c+\frac{r-K}{T-K}$, where c is to be determined by α. To find c for a given α is quite complicated. Brown et al. suggest consulting a table of significance values of Pyke's (1959) modified Kolmogorov-Smirnov statistic, C_n, which is to be entered at $n=\frac{1}{2}(T-K)-1$. This table is reproduced in the appendix.

A similar CUSUM of squares procedure can also be based on OLS-residuals (McCabe and Harrison, 1980).

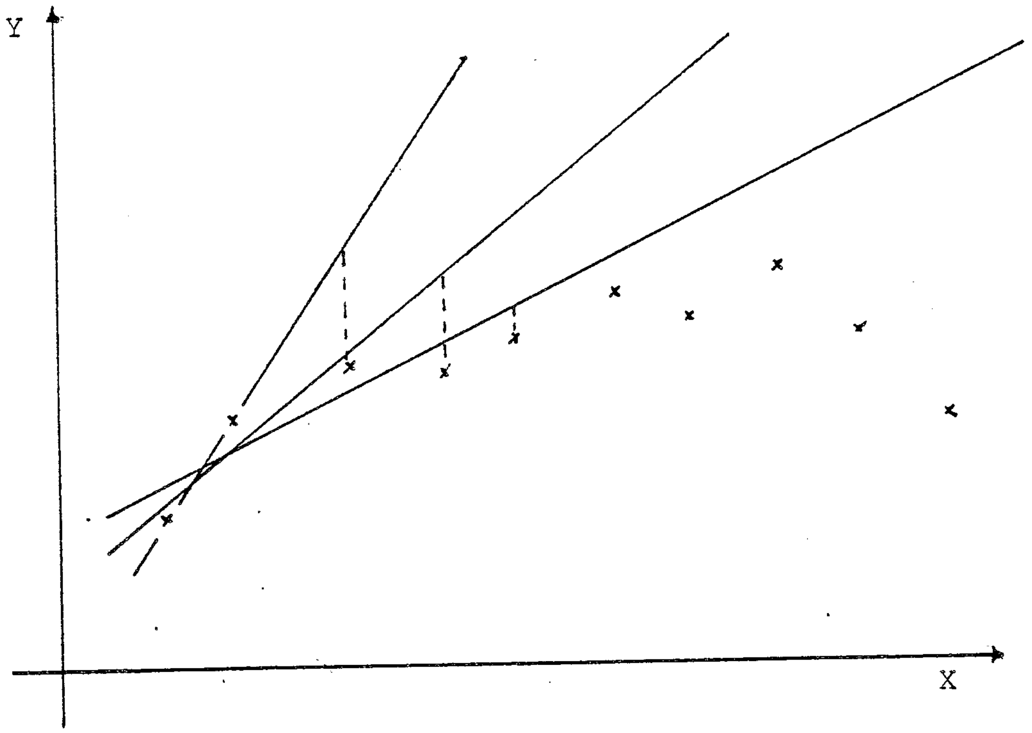
Recursive residuals may also be used to detect functional misspecification in a regression equation. This may with some justice be viewed as the most important problem in all of applied econometrics, where the assumption of a linear relationship between dependent and independent variables is often more a matter of convenience rather than theory. Harvey and Collier (1977) suggest a simple test of this assumption for the case where the functional form of only one of the regressors, say x_j, is in doubt. The test procedure then consists simply of arranging the observations in ascending (or descending) order according to x_j, and computing the statistic

$$(2-23) \qquad \Psi = \left[\frac{\sum_{r=K+1}^{T} (w_r-\bar{w}_r)^2}{T-K-1}\right]^{-1/2} \cdot (T-K)^{1/2} \sum_{r=K+1}^{T} w_r \ .$$

The logic of this procedure is perhaps best seen by considering the bivariate case depicted in Figure 1:

FIGURE 1

Derivation of recursive residuals for a misspecified bivariate regression model



When the regression is linear and $u \sim N(0, \sigma^2 I)$, Ψ follows a t-distribution with T-K-1 degrees of freedom. On the other hand, when y is a convex function of x_j, the recursive residuals, being just the forecasting errors standardised, will tend to be positive. Conversely when y is a concave function of x_j they will tend to be negative. In either case Ψ will be large in absolute value. The null hypothesis of linearity is therefore rejected whenever $|\Psi|$ is too large.

A similar idea leads to what J. Utts has called the "rainbow test" for lack of fit in regression. To motivate the procedure, consider the bivariate scatter plot shown in Figure 2. The correct model is quadratic, but a straight line has been fit. If one considers only a subset of the points corresponding to the central region of the independent variable, then the (incorrect) linear fit is not too far from the true model. However, when the model is fit over the entire range of the independent variable, the variance of the OLS-residuals will increase drastically.

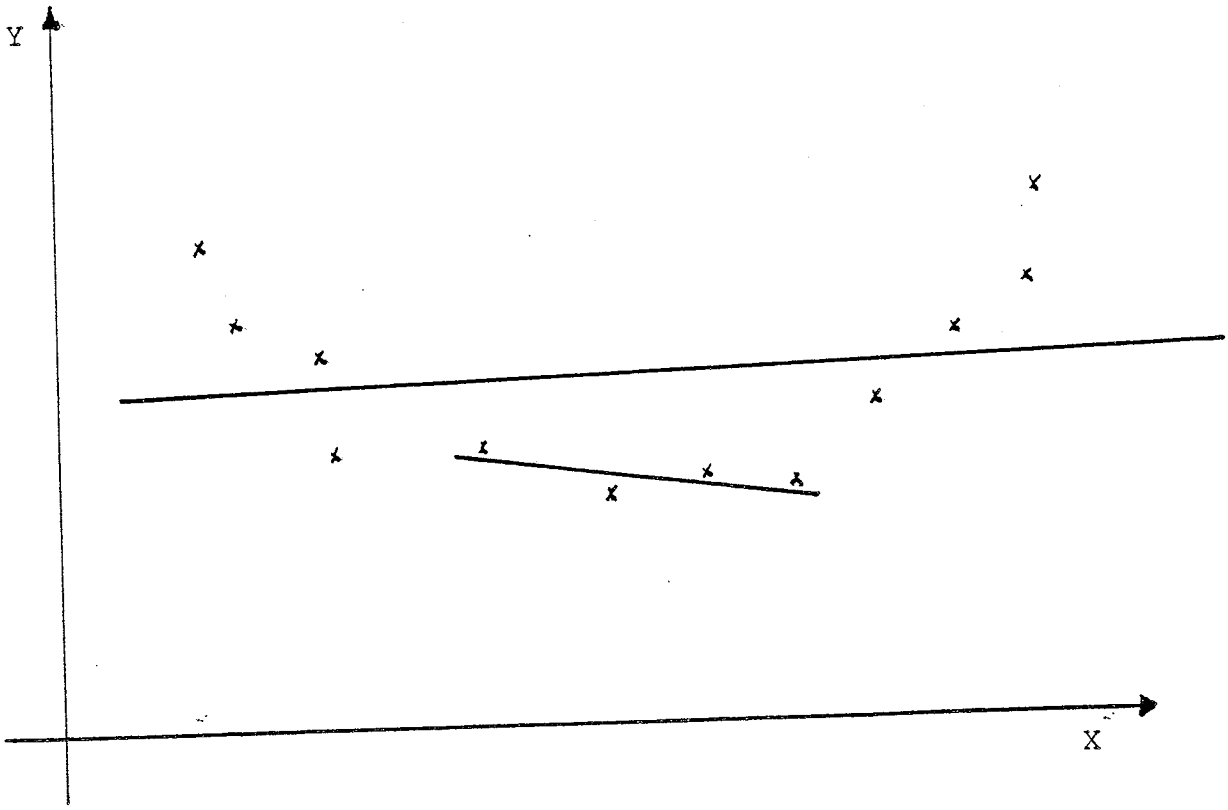
In general, the test is based on first fitting the T_1 data points with least leverage (smallest diagonal elements in $X(X'X)^{-1}X'$) and comparing the residual sum of squares to that obtained when all data are fitted. The test statistic is

$$(2\text{-}24) \qquad F = \frac{(\Sigma_{t=1}^{T}\hat{u}_t^2 - \Sigma_{t=1}^{T_1}\hat{u}_t^{(1)^2})(T-T_1)}{(\Sigma_{t=1}^{T_1}\hat{u}_t^{(1)^2})/(T_1-K)}$$

where the $\hat{u}_t^{(1)}$'s are the residuals of the restricted regression. F has an F-distribution with $T-T_1$ and T_1-K degrees of freedom, and the null hypothesis of a linear model should be rejected whenever F is too large.

FIGURE 2

Partial fit versus overall fit



The standard test for functional misspecification is Ramsey's (1969) RESET-procedure. This amounts to using the standard F-test to test whether Θ=0 in the augmented equation

(2-25) $y = X\beta + Z\theta + u$,

where Z is a matrix of test variables. Alternative sets of test variables offered by the IAS-SYSTEM are (i) powers of the explanatory variables, (ii) powers of the fitted y-values, and (iii) powers of principal components of X. The rationale behind this is that if y_t is some analytical function of X_t, it can be approximated by a Taylor-series expansion involving powers of the explanatory variables. Thursby and Schmidt (1977) discuss the power of the test for alternative test variables, and Thursby (1979) compares RESET to other specification tests. Note that all variants of the test except (iii) can easily be computed by hand.

Godfrey and Wickens (1981) test the correctness of the linear specification by viewing it as a special case of the Box-Cox transformation

(2-26)
$$\begin{aligned} z(\lambda) &= (z^{\lambda}-1)/\lambda & \lambda &\neq 0 \\ &= \log(z) & \lambda &= 0 \\ &= z-1 & \lambda &= 1 \quad , \end{aligned}$$

where z stands for y_t and x_{it} $(t=1,\ldots,T;\ i=1,\ldots,K)$. The adequacy of the linear specification is, therefore, equivalent to the restriction $\lambda=1$. This is tested by applying a standard LM-procedure, where the test statistic is asymptotically distributed as $\chi^2_{(1)}$ under H_o. The same rationale leads to an analogous test of the null hypothesis that the logarithmic specification is correct $(\lambda=0)$.

A major drawback of this procedure is that all the tested variables have to be positive, even for testing the correctness of the linear specification.

To facilitate discrimination between a linear and a log-linear functional form, the IAS-SYSTEM also provides Sargan's S, defined as

$$(2\text{-}27) \qquad S = \left(\frac{\hat{\sigma}^2}{g\tilde{\sigma}^2}\right)^{\frac{T}{2}}$$

where $\hat{\sigma}^2$ is the ML-estimate of the error variance under the linear specification, $\tilde{\sigma}^2$ is the ML-estimate of the error variance under the log-linear specification, and g is the geometric mean of $y_1,...,y_T$. It is easily checked that S is the ratio of the maximized likelihoods for the case in which the errors, both for the linear and log-linear specification, are independent normal. If $S<1$, then the data can be said to favour the linear model, and if $S>1$, the log-linear model is preferred. Note that g and thus S cannot be computed when some y_t's are nonpositive, in which case, however, the log-linear model is ruled out anyway.

Another problem which might also be viewed as a misspecification of the functional form occurs when there is an outlier in the regression. Assuming the mean-shift outlier model (see Cook and Weisberg, 1982, Section 2.2.2) an easy test whether observation t is an outlier is available by considering the augmented model

(2.28) $$y = X\beta + d_t\alpha + u ,$$

where d_t is a T-vector with t'th element equal to one, and all other elements equal to zero. Significant values of the t-statistic for α imply the t'th observation is an outlier. The IAS-SYSTEM also computes the maximum of all these t-statistics for $t=1,\ldots,T$, which furnishes a test for the presence of a single outlier at an unknown point in time. Significance levels of this test are tabulated in the appendix.

d) Errors in variables

Hausman (1978) has suggested a general form of specification test, which in the IAS-SYSTEM is used to test for errors in the exogenous variables. The theory underlying Hausman's approach rests on a very simple but fundamental idea. If a model is correctly specified, estimates by any two consistent estimators should be close together. If they are not, there is reason to believe that something is wrong.

To formalize this idea, denote by $\hat{\beta}_o$ an estimator which is consistent, asymptotically normal and asymptotically efficient under the null hypothesis of no misspecification. In most applications, this will be OLS. Under the alternative hypothesis of misspecification, however, this estimator will be biased and inconsistent. To construct a test of misspecification, another estimator, $\hat{\beta}_1$ is needed which is not adversely affected by the misspecification. This estimator will not however, be asymptotically efficient under the null hypothesis. If no misspecification is present, $\hat{q}=\hat{\beta}_1-\hat{\beta}_o$ tends to zero. With misspecification, plim q will differ from zero. Hausman then shows that the test statistic

$$(2\text{-}29) \qquad m = T\hat{q}'[\hat{V}(\hat{q})]^{-1}\hat{q}$$

will be asymptotically distributed as $\chi^2_{(K)}$ under H_o, where $\hat{V}(\hat{q})$ may be any consistent estimate of $V(\hat{q})$, the covariance matrix of the asymptotic distribution of $\sqrt{T\hat{q}}$.

Since $\hat{\beta}_o$ is asymptotically efficient, it is asymptotically uncorrelated with $\hat{\beta}_o-\hat{\beta}_1$ and $V(\hat{q})=V(\hat{\beta}_1)-V(\hat{\beta}_o)$ >0. Some modifications are necessary when $V(\hat{q})$ is singular, an issue recently adressed by Hausman and Taylor (1980) and Holly (1982).

For the special case where the null hypothesis is that the model obeys the assumptions of standard linear regression and the alternative stipulates errors in some or all exogenous variables, $\hat{\beta}_o$ is the OLS-estimate of β and $\hat{\beta}_1$ is an instrumental variable estimate where the instruments must be supplied by the user. Both $\hat{\beta}_o$ and $\hat{\beta}_1$ will be consistent under H_o, while $\hat{\beta}_o$ will also be efficient, but inconsistent under H_1.

Another test along these lines has recently been suggested by Plosser, Schwert and White (1982). It is meant to supply a general test that the assumptions of the standard linear regression model apply, without specifying a particular alternative. It is based on comparing the OLS-estimate of (1), $\hat{\beta}$, with the OLS-estimate obtained after first differencing, $\tilde{\beta}$. When the model is correctly specified, $\tilde{\beta}$ is also a consistent (although inefficient) estimator for β, provided that X contains no lagged endogenous variables. The inefficiency of $\tilde{\beta}$ arises from the fact that differencing induces a first order moving average process in the disturbances of the differenced model.

The covariance matrix of $\tilde{\beta}$ is

$$\sigma^2 (X'X)^{-1} X'D'DX(X'X)^{-1} \quad ,$$

where

$$D = \begin{bmatrix} -1 & 1 & & 0 & \\ 0 & -1 & 1 & & \\ & & \vdots & \vdots & \\ & & & -1 & 1 \end{bmatrix}$$

is the familiar first difference matrix, leading to the test statistic:

$$(2\text{-}30) \qquad \sigma = Ts^2(\hat{\beta}-\tilde{\beta})'[(X'X)^{-1}\ X'D'D'X\ (X'X)^{-1}-(X'X)^{-1}](\hat{\beta}-\tilde{\beta}),$$

which has an asymptotic χ_K^2 distribution when the model is correctly specified. When there is a constant in the regression, there are only K-1 elements in $\tilde{\beta}$ (since the intercept cannot be estimated by first differencing), and the statistic has to be adjusted accordingly.

This test has power and is consistent against any alternative that leads to different probability limits for $\tilde{\beta}$ and $\hat{\beta}$. One special case where this is always the case is when there are errors in variables. However, this test has power against a much wider range of specification errors, which need not be specified in advance, which makes it very attractive from an applications viewpoint.

In the lagged dependent variable case some of the regressors are correlated with the errors of the differenced model, so $\tilde{\beta}$ is inconsistent even under the null hypothesis of no miss-specification and the procedure breaks down. For the necessary amendments in this case see Plosser et al. (1982).

The Plosser-Schwert-White procedure is in the class of what Pagan (1982) has tentatively called "transformational tests". Such tests exploit the fact that estimators of a correct model should remain consistent under finite linear transformation. That is, if (2) is correct, $\hat{\beta}$ and the OLS estimator of β applied to $Fy = FX+Fu$ should both converge to β. F corresponds to the differencing matrix D for the test described above. Another test along these lines has recently been suggested by Farebrother (1979), where F is defined such that it aggregates data.

3. The IAS-SYSTEM Test Processor in Practice

This section reports the results of applying the procedures reviewed above to some recent data from the Austrian economy. The user can thereby familiarize himself with the IAS-SYSTEM test processor and at the same time get some guidance on how to proceed in his own particular application. For detailed instructions on how to call the several subroutines of the test processor and the input required see Maurer et al. (1983). Havlik and Sonnberger (1983) provides an in depth discussion of the test processor from a software-technology viewpoint, and additional applications are given in Krämer et al. (1983).

We will demonstrate the usefulness of the tests via three examples, each from a typical area of application of the IAS-SYSTEM. The necessary data are reproduced in the appendix.

a) Estimating the demand for durable consumer goods: yearly data

Estimating a consumption function is a standard problem in empirical econometrics. We start out with the following simple equation:

(3-1) $$cd = b_1 \cdot yd + b_2 (yd \cdot rr) + b_3 + u$$

$$= yd (b_1 + b_2 \cdot rr) + b_3 + u$$

where cd = real consumption of durables
yd = real disposable income
rr = real interest rate (prime rate minus rate of change of the private consumption deflator)

Table 1 reports the OLS-estimates of (1).

We now proceed to test the assumptions underlying (1) and the OLS-Method of estimation, testing in turn for (i) stability of the regression parameters (ii) correct specification of the functional form, and (iii) possible problems with the error terms.

(i) We first let the system calculate Quandt-ratios to get an idea where a possible structural break might have occurred. Similar information is provided by the Cusum and Cusum of squares tests, where the table of recursive parameter estimates is of additional help in locating possible break points. We also applied the Chow test by splitting the sample where the Quandt-ratio attained its minimum. This of course inflates the size of the test well above its nominal α-level, but may nevertheless yield additional insights.

Tables 2-4 give the results of these tests. Both Quandt and Chow point towards a structural change beginning in 1978, though none is very significant.

(ii) Parallel to (i), we tested for correctness of the functional form of (1). Specifying the functional form of an economic relationship is perhaps the most difficult task in all applied econometrics, and we started with a linear form mostly for convenience. In particular, one might doubt whether yd·rr indeed enters the equation in a linear way. We therefore applied the Harvey-Collier test to this variable. As additional diagnostic checks, we also applied Ramsey's Reset test, the Plosser-Schwer-White differencing test and the Rainbow test. Tables 5-6 give the results. None of the tests furnishes strong evidence against the linear specification.

(iii) Being reasonably assured that the deterministic part of the model is correct, one can turn to the error terms. Since (1) is estimated in levels over a fairly long period, one might for instance suspect the error variance to increase over time. Tables 7-9 report the results of applying the corresponding tests from the IAS-SYSTEM to this problem. We used real disposable income as the explanatory variable for the Breusch-Pagan test.

All tests allow the homoscedasticity assumption to be maintained. This is also supported by the fact that White's heteroscedasticity-adjusted t-values are quite close to the OLS-estimated ones. As to possible autocorrelation, neither the Durbin-Watson test (Table 1) nor the LM-test for simple autocorrelation discussed on p. 43 (Table 10) suggest that there is any problem here.

This cannot be said for the outlier test and the Jarque-Bera test for normality (Table 11). Though not significant at the 5 % level, the Jarque-Bera statistic is well above what one routinely gets in such equations. This might be because of possible outliers in 1972 and 1977. Both years witnessed announced changes in Austrian tax laws, causing consumers to speed up investment in durables. This could also explain why a structural break starting 1978 is suggested by the Quandt and Chow tests.

To discriminate between the structural-break and single outlier hypotheses, we reestimated (1) with additional dummies for 1972 and 1977. Table 13 gives the results, which are pretty much in line with Table 1. (To remind the user which equation he is working with, the current equation can be recalled by the MEMO statement; see Table 12).

Because of rank deficiencies in the regressor matrices when dummies are included and the sample is split, the IAS-SYSTEM does not provide the Chow and Quandt tests in this case.

However, the Cusum and Cusum of squares tests have been modified to allow for a maximum of two dummies (in addition to the constant), and the results are given in Table 14-15. None of the tests suggests a structural break any more.

Since the model passes the other tests as well (Tables 16-19), we conclude that equation (1), with two tax-policy dummies added, might be viewed as a satisfactory explanation of the consumption of durable goods in Austria.

```
---> *t,est 65:82
 OK
---> *o
IAS-SYSTEM Estimation Processor
Dependent variable of the equation ?
---> cd
Explanatory variables of the equation ?
---> yd
---> yd*rr
---> *



OLS   Estimation


      List of Labels


      CD                  Durable Consumption/real P76
      YD                  Disposable Income/real P76
      Var1                YD*RR
      CONST               Constant Term



==========================================================================
DEP. VARIABLE:  CD                                 I R2   .929 I R2C   .920
--------------------------------------------------------------------------
Nr.I Predetermined Variables            I Est. Coeff.I St. Dev.  I   t   I BC %
--------------------------------------------------------------------------
   I                                    I            I           I       I
B1 I YD                                 I      .16249 I    .01273 I 12.76 I 79.6
   I                                    I            I           I       I
B2 I Var1                               I     -.00477 I    .00146 I  3.26 I 20.4
   I                                    I            I           I       I
B3 I CONST                              I   -15.50123 I   4.31099 I  3.60 I   .0
   I                                    I            I           I       I
--------------------------------------------------------------------------
SE     3.27919  I  MAPE       5.16  I 65   -82   I DW  2.061 I RHO(1)  -.10
==========================================================================
```

Table 1

```
---> **quandt

****************************************************************************

       Plot Diagram of Quandt-Ratios
       -----------------------------

       =======================================================
       Period  I   Ratio   I      * ... Quandt Ratios       I
       -------------------------------------------------------
       1968    I    -8.368 I    *                           I
       1969    I    -8.363 I    *                           I
       1970    I    -8.997 I *                              I
       1971    I    -5.630 I                  *             I
       1972    I    -3.240 I                              * I
       1973    I    -3.477 I                             *  I
       1974    I    -3.239 I                              * I
       1975    I    -3.305 I                              * I
       1976    I    -3.828 I                           *    I
       1977    I    -9.013 I *                              I
       1978    I    -4.777 I                        *       I
       =======================================================

                 MIN (Quandt-Ratios) at   1977
                 New regime starting at   1978

****************************************************************************

---> **chow 78

****************************************************************************

             Chow-Test for Parameter Stability
             ---------------------------------

             H0: All parameters are stable over:  1965    - 1982
             H1: At least one parameter changes at:         1978

             Value of Chow-Statistic:       3.541
             Under H0: F( 3, 12)

****************************************************************************
```

Table 2

```
---> **cusum 5
Insert regression parameters to be printed
---> B1,B2,B3

********************************************************************************

                 Table of Recursive Regression Parameters
                 ----------------------------------------

                B1        B2         B3
 -67          .4643    -.0052   ********
 -68          .0913     .0006      .2783
 -69          .0532     .0011    11.1283
 -70          .0979     .0001    -1.3910
 -71          .1510    -.0011   -16.5325
 -72          .2046    -.0028   -31.4277
 -73          .1952    -.0023   -28.9913
 -74          .1832    -.0017   -25.7800
 -75          .1761    -.0016   -23.5667
 -76          .1699    -.0015   -21.5866
 -77          .1841    -.0020   -25.8091
 -78          .1711    -.0036   -19.7662
 -79          .1691    -.0042   -18.3551
 -80          .1639    -.0046   -16.1412
 -81          .1627    -.0050   -15.3018
 -82          .1625    -.0048   -15.5024


                  Regression Constancy - CUSUM Test
                  ---------------------------------

************************************************************************
I TIME  I   VALUE OF THE TEST STATISTIC    I   5% I  UPPER BOUND  I
************************************************************************
I -68   I                  -.231           I  0  I     4.161      I
I -69   I                  -.513           I  0  I     4.651      I
I -70   I                  -.151           I  0  I     5.140      I
I -71   I                   .765           I  0  I     5.630      I
I -72   I                  2.322           I  0  I     6.119      I
I -73   I                  1.969           I  0  I     6.609      I
I -74   I                  1.231           I  0  I     7.098      I
I -75   I                   .674           I  0  I     7.588      I
I -76   I                   .090           I  0  I     8.077      I
I -77   I                  1.773           I  0  I     8.567      I
I -78   I                  -.366           I  0  I     9.057      I
I -79   I                  -.936           I  0  I     9.546      I
I -80   I                 -2.277           I  0  I    10.036      I
I -81   I                 -3.017           I  0  I    10.525      I
I -82   I                 -2.740           I  0  I    11.015      I
************************************************************************
```

Table 3

```
---> **cusum2 5
Insert regression parameters to be printed
---> B1,B2,B3
Insert table significance value for test (IAS-Manual: C( 6.5)):
---> .392
*******************************************************************************

                   Table of Recursive Regression Parameters
                   ----------------------------------------

           B1        B2        B3
-67      .4643    -.0052   ********
-68      .0913     .0006      .2783
-69      .0532     .0011    11.1283
-70      .0979     .0001    -1.3910
-71      .1510    -.0011   -16.5325
-72      .2046    -.0028   -31.4277
-73      .1952    -.0023   -28.9913
-74      .1832    -.0017   -25.7800
-75      .1761    -.0016   -23.5667
-76      .1699    -.0015   -21.5866
-77      .1841    -.0020   -25.8091
-78      .1711    -.0036   -19.7662
-79      .1691    -.0042   -18.3551
-80      .1639    -.0046   -16.1412
-81      .1627    -.0050   -15.3018
-82      .1625    -.0048   -15.5024

                 Regression Constancy - Cusum of Squares Test
                 --------------------------------------------

 ************************************************************************
 I TIME I LOWER BOUND I VALUE OF TEST STATISTIC I UPPER BOUND I  5% I
 ************************************************************************
 I 68   I    -.3253   I         .0036           I     .4587   I  0  I
 I 69   I    -.2587   I         .0089           I     .5253   I  0  I
 I 70   I    -.1920   I         .0176           I     .5920   I  0  I
 I 71   I    -.1253   I         .0735           I     .6587   I  0  I
 I 72   I    -.0587   I         .2351           I     .7253   I  0  I
 I 73   I.    .0080   I         .2434           I     .7920   I  0  I
 I 74   I     .0747   I         .2797           I     .8587   I  0  I
 I 75   I     .1413   I         .3004           I     .9253   I  0  I
 I 76   I     .2080   I         .3231           I     .9920   I  0  I
 I 77   I     .2747   I         .5119           I    1.0587   I  0  I
 I 78   I     .3413   I         .8168           I    1.1253   I  0  I
 I 79   I     .4080   I         .8385           I    1.1920   I  0  I
 I 80   I     .4747   I         .9584           I    1.2587   I  0  I
 I 81   I     .5413   I         .9949           I    1.3253   I  0  I
 I 82   I     .6080   I        1.0000           I    1.3920   I  0  I
 ************************************************************************
```

Table 4

```
---> **harvey
Insert position of tested variable
---> 2

***************************************************************************

          Harvey-Collier Psi-Test for Functional Misspecification
          -------------------------------------------------------

               H0: Equation linear in variable No.  2
               H1: Equation non-linear in this variable

               Value of Test-Statistic:     -1.126
               Under H0: t( 14)

               ----------------------------------------
               Value of Durbin-Watson Statistic:  2.022
               Pos. Recursive Residuals:   5 out of  15

***************************************************************************
```

```
---> **reset,p 2

***************************************************************************

               Ramsey's Reset Test
               -------------------

               H0: Standard assumptions of OLS-regression are valid
               H1: Model Specification is incorrect

               Value of Test-Statistic:       2.398
               Under H0: F( 2, 13)

               Test variables: Powers 2- 3 of first principal comp.
***************************************************************************
```

Table 5

```
---> **rbow

***************************************************************************

              The Rainbow Test for Lack of Fit
              --------------------------------

                  H0: Model is correct
                  H1: Model is not correct

              Value of test statistic     1.234
              Under H0:  F(  9,  6)

             9 Low leverage points used for regression

***************************************************************************
```

```
---> **diff

***************************************************************************

     Plosser-Schwert-White Differencing Test for Model Specification
     ---------------------------------------------------------------

          H0: Standard assumptions of OLS-regression are valid
          H1: Model Specification is incorrect

                OLS-coefficient       First-difference
                   Estimates             Estimates

          B1          .16249                .18526
          B2        -.00477               -.00295

          Value of Test-Statistic:       2.433
          Under H0: Chi-square ( 2)

***************************************************************************
```

Table 6

```
---> **hetero


**********************************************************************

           LM-Test for specific Heteroscedasticity
           ------------------------------------

           H0: Variance of residuals constant
           H1: Variance of residuals proportional to E(y)

           Value of Test-Statistic:       .471
           Under H0: Chi-square(1)

**********************************************************************





---> **bp 1
Which variables should explain heteroscedasticity
---> yd


**********************************************************************

           Breusch-Pagan Test for Heteroscedasticity
           --------------------------------------

           H0: Residuals are homoscedastic
           H1: Variance depends on specified variables

           Value of Test-Statistic:       .356
           Under H0: Chi-square ( 1)

**********************************************************************
```

Table 7

```
---> **gq
```

```
**************************************************************************

          Goldfeld-Quandt Test for Heteroscedasticity
          -------------------------------------------

          H0: Residuals are homoscedastic
          H1: Residuals are heteroscedastic

          Value of Test-Statistic:       .513
          Under H0: F( 6,  6)

      Number of observations deleted in the middle of the sample:   0

**************************************************************************
```

Table 8

```
---> **white



****************************************************************************

          White's Test for General Heteroscedasticity
          -------------------------------------------

          H0: Residuals are homoscedastic
          H1: Residuals are heteroscedastic

          Value of Test-Statistic:       3.643
          Under H0: Chi-square ( 6)

****************************************************************************


---> **atv



****************************************************************************

          White's Heteroscedasticity adjusted t-values
          --------------------------------------------

          Parameters       t-values        adj. t-values

             B1             12.760           12.822
             B2              3.261            3.377
             B3              3.596            4.053
****************************************************************************
```

Table 9

```
---> **ar 3



************************************************************************

          LM-Test for simple Autocorrelation
          ----------------------------------

          Model: u=rho*u[j]+eps
            H0: rho.EQ.0
            H1: rho.NE.0

          Lag(j)     Aut. coeff.     Value of Test-Statistic

            1           -.095               -.403
            2           -.108               -.458
            3           -.236              -1.001

          Under H0: N(0,1)

  Warning: Test statistic valid only without lagged endogenous variables
************************************************************************
```

Table 10

```
---> **normal

****************************************************************************

            Jarque-Bera Test for Normality of Residuals
            -------------------------------------------

            H0: Residuals are normally distributed
            H1: Residuals are not normally distributed

              Sum of residuals                  .000
              Sum of residuals**2              8.961
              Sum of residuals**3             23.206
              Sum of residuals**4            279.042

            Value of Jarque-Bera Statistic:      2.415
            Under H0: Chi-square(2)

****************************************************************************

---> **outlie

****************************************************************************

       Plot-Diagram of t-statistics of Outlier Coefficients
       ----------------------------------------------------

       =======================================================
        Period  I  t-value  I      * ... t-statistics        I
       -------------------------------------------------------
        1965    I    -1.768 I *                              I
        1966    I      .026 I            *                   I
        1967    I      .923 I                 *              I
        1968    I     -.175 I          *                     I
        1969    I     -.342 I         *                      I
        1970    I     -.595 I        *                       I
        1971    I      .507 I               *                I
        1972    I     2.264 I                          *     I
        1973    I      .276 I             *                  I
        1974    I     -.359 I         *                      I
        1975    I     -.030 I           *                    I
        1976    I     -.230 I          *                     I
        1977    I     3.039 I                              * I
        1978    I    -1.275 I    *                           I
        1979    I      .120 I            *                   I
        1980    I    -1.172 I    *                           I
        1981    I     -.778 I       *                        I
        1982    I      .269 I             *                  I
       =======================================================

            MAX ABS(t-value) at 1977        3.039
            Significance Points:   see IAS-Manual

****************************************************************************
```

Table 11

```
---> **memo

*********************************************************************************

       Estimated Equation
       ------------------

          Endogenous Variable:     CD

          Exogenous Variables:  1. YD
                                2. YD*RR
                                3. CONST
          1965     - 1982
*********************************************************************************
```

Table 12

```
---> *o
IAS-SYSTEM Estimation Processor
Dependent variable of the equation ?
---> cd
Explanatory variables of the equation ?
---> dtp72
---> dtp77
---> yd
---> yd*rr
---> *

OLS   Estimation


      List of Labels


      CD                  Durable Consumption/real P76
      DTP72               Dummy Tax-policy 1972
      DTP77               Dummy Tax-policy 1977
      YD                  Disposable Income/real P76
      Var1                YD*RR
      CONST               Constant Term



=============================================================================
 DEP. VARIABLE:  CD                                I R2    .979 I R2C   .973
-----------------------------------------------------------------------------
 Nr.I Predetermined Variables            I Est. Coeff.I St. Dev.  I   t   I BC %
-----------------------------------------------------------------------------
    I                                    I            I           I       I
 B1 I DTP72                              I    7.28729 I   1.97378 I  3.69 I  9.5
    I                                    I            I           I       I
 B2 I DTP77                              I    9.54982 I   2.17034 I  4.40 I 12.5
    I                                    I            I           I       I
 B3 I YD                                 I     .14970 I    .00806 I 18.56 I 65.8
    I                                    I            I           I       I
 B4 I Var1                               I    -.00318 I    .00092 I  3.45 I 12.2
    I                                    I            I           I       I
 B5 I CONST                              I  -13.46398 I   2.61058 I  5.16 I   .0
    I                                    I            I           I       I
-----------------------------------------------------------------------------
 SE      1.91007  I  MAPE        3.47 I 65    -82    I DW  1.704 I RHO(1)   .05
=============================================================================
```

Table 13

```
---> **cusum,d 5
Insert regression parameters to be printed
---> B1,B2,B3,B4,B5
How many dummies are present in the regression (max 2 allowed) ?
---> 2

******************************************************************************

                 Table of Recursive Regression Parameters
                 ----------------------------------------

             B1         B2         B3         B4         B5
 -67       .0000      .0000      .4643     -.0052    ********
 -68       .0000      .0000      .0913      .0006      .2783
 -69       .0000      .0000      .0532      .0011    11.1283
 -70       .0000      .0000      .0979      .0001    -1.3910
 -71       .0000      .0000      .1510     -.0011   -16.5325
 -72      7.2655      .0000      .1510     -.0011   -16.5287
 -73      5.6660      .0000      .1759     -.0021   -23.2093
 -74      5.9462      .0000      .1714     -.0020   -21.9728
 -75      6.0727      .0000      .1693     -.0020   -21.3370
 -76      6.2406      .0000      .1663     -.0019   -20.3820
 -77      6.2406     7.4511      .1663     -.0019   -20.3820
 -78      6.9684     8.8633      .1553     -.0028   -15.7725
 -79      7.0092     8.9093      .1548     -.0029   -15.4933
 -80      7.2124     9.4058      .1508     -.0031   -13.9534
 -81      7.3034     9.5067      .1499     -.0033   -13.3612
 -82      7.2873     9.5498      .1497     -.0032   -13.4640

                    Regression Constancy - CUSUM Test
                    ---------------------------------

 ************************************************************************
 I TIME  I   VALUE OF THE TEST STATISTIC     I   5% I  UPPER BOUND  I
 ************************************************************************
 I -68   I                 -.397             I   0  I      3.944    I
 I -69   I                 -.882             I   0  I      4.470    I
 I -70   I                 -.259             I   0  I      4.996    I
 I -71   I                 1.313             I   0  I      5.521    I
 I -73   I                 2.343             I   0  I      6.047    I
 I -74   I                 1.947             I   0  I      6.573    I
 I -75   I                 1.700             I   0  I      7.099    I
 I -76   I                 1.241             I   0  I      7.625    I
 I -78   I                -1.067             I   0  I      8.151    I
 I -79   I                -1.248             I   0  I      8.677    I
 I -80   I                -2.689             I   0  I      9.202    I
 I -81   I                -3.554             I   0  I      9.728    I
 I -82   I                -3.274             I   0  I     10.254    I
 ************************************************************************
```

Table 14

```
---> **cusum2,d 5
Insert regression parameters to be printed
---> B1,B2,B3,B4,B5
Insert table significance value for test (IAS-Manual: C( 5.5)):
---> .411
How many dummies are present in the regression (max 2 allowed) ?
---> 2

*****************************************************************************

               Table of Recursive Regression Parameters
               ----------------------------------------

            B1          B2          B3         B4          B5
 -67       .0000       .0000       .4643     -.0052     ********
 -68       .0000       .0000       .0913      .0006       .2783
 -69       .0000       .0000       .0532      .0011     11.1283
 -70       .0000       .0000       .0979      .0001     -1.3910
 -71       .0000       .0000       .1510     -.0011    -16.5325
 -72      7.2655       .0000       .1510     -.0011    -16.5287
 -73      5.6660       .0000       .1759     -.0021    -23.2093
 -74      5.9462       .0000       .1714     -.0020    -21.9728
 -75      6.0727       .0000       .1693     -.0020    -21.3370
 -76      6.2406       .0000       .1663     -.0019    -20.3820
 -77      6.2406      7.4511       .1663     -.0019    -20.3820
 -78      6.9684      8.8633       .1553     -.0028    -15.7725
 -79      7.0092      8.9093       .1548     -.0029    -15.4933
 -80      7.2124      9.4058       .1508     -.0031    -13.9534
 -81      7.3034      9.5067       .1499     -.0033    -13.3612
 -82      7.2873      9.5498       .1497     -.0032    -13.4640

             Regression Constancy - Cusum of Squares Test
             --------------------------------------------

 *****************************************************************
 I TIME I LOWER BOUND I VALUE OF TEST STATISTIC I UPPER BOUND I  5% I
 *****************************************************************
 I 68   I    -.3341   I          .0121          I      .4879  I  0  I
 I 69   I    -.2572   I          .0302          I      .5648  I  0  I
 I 70   I    -.1802   I          .0600          I      .6418  I  0  I
 I 71   I    -.1033   I          .2501          I      .7187  I  0  I
 I 73   I    -.0264   I          .3317          I      .7956  I  0  I
 I 74   I     .0505   I          .3437          I      .8725  I  0  I
 I 75   I     .1275   I          .3484          I      .9495  I  0  I
 I 76   I     .2044   I          .3647          I     1.0264  I  0  I
 I 78   I     .2813   I          .7742          I     1.1033  I  0  I
 I 79   I     .3582   I          .7767          I     1.1802  I  0  I
 I 80   I     .4352   I          .9364          I     1.2572  I  0  I
 I 81   I     .5121   I          .9940          I     1.3341  I  0  I
 I 82   I     .5890   I         1.0000          I     1.4110  I  0  I
 *****************************************************************
```

Table 15

```
---> **hetero

***************************************************************************

           LM-Test for specific Heteroscedasticity
           ---------------------------------------

           H0: Variance of residuals constant
           H1: Variance of residuals proportional to E(y)

           Value of Test-Statistic:       .461
           Under H0: Chi-square(1)

***************************************************************************




---> **bp 1
Which variables should explain heteroscedasticity
---> yd


***************************************************************************

           Breusch-Pagan Test for Heteroscedasticity
           -----------------------------------------

           H0: Residuals are homoscedastic
           H1: Variance depends on specified variables

           Value of Test-Statistic:       .788
           Under H0: Chi-square ( 1)

***************************************************************************
```

Table 16

```
---> **ar 3




***************************************************************************

          LM-Test for simple Autocorrelation
          ----------------------------------

          Model: u=rho*u[j]+eps
             H0: rho.EQ.0
             H1: rho.NE.0

          Lag(j)     Aut. coeff.     Value of Test-Statistic

            1            .055                   .231
            2            .016                   .069
            3            .005                   .022

          Under H0: N(0,1)

  Warning: Test statistic valid only without lagged endogenous variables
***************************************************************************
```

Table 17

```
---> **diff



*******************************************************************************

    Plosser-Schwert-White Differencing Test for Model Specification
    ----------------------------------------------------------------

           H0: Standard assumptions of OLS-regression are valid
           H1: Model Specification is incorrect

                  OLS-coefficient      First-difference
                     Estimates            Estimates

           B1         7.28729              4.52678
           B2         9.54982             11.23367
           B3          .14970               .15731
           B4        -.00318              -.00058

           Value of Test-Statistic:     9.238
           Under H0: Chi-square ( 4)

*******************************************************************************
```

Table 18

```
---> **normal


****************************************************************************

            Jarque-Bera Test for Normality of Residuals
            -------------------------------------------

            H0: Residuals are normally distributed
            H1: Residuals are not normally distributed

              Sum of residuals                     .000
              Sum of residuals**2                 2.635
              Sum of residuals**3                 -.824
              Sum of residuals**4                13.427

            Value of Jarque-Bera Statistic:         .964
            Under H0: Chi-square(2)

****************************************************************************

---> **outlie


****************************************************************************

       Plot-Diagram of t-statistics of Outlier Coefficients
       ----------------------------------------------------

       ========================================================
        Period  I  t-value  I       * ... t-statistics        I
       --------------------------------------------------------
        1965    I    -2.130 I *                               I
        1966    I      .226 I                    *            I
        1967    I     1.150 I                            *    I
        1968    I     -.244 I                 *               I
        1969    I     -.756 I            *                    I
        1970    I     -.791 I            *                    I
        1971    I     1.197 I                            *    I
        1972    I      .000 I                   *             I
        1973    I     1.617 I                               * I
        1974    I      .485 I                      *          I
        1975    I      .934 I                          *      I
        1976    I      .781 I                         *       I
        1977    I      .000 I                   *             I
        1978    I    -1.419 I       *                         I
        1979    I      .526 I                       *         I
        1980    I    -1.232 I         *                       I
        1981    I     -.903 I           *                     I
        1982    I      .270 I                     *           I
       ========================================================


            MAX ABS(t-value) at 1965          2.130
            Significance Points:   see IAS-Manual


****************************************************************************
```

Table 19

b) Estimating the demand for durable consumer goods: quarterly data

With quarterly data, adjustment mechanisms become important. The following analysis extends the model of subsection a) by assuming

$$(3\text{-}2) \qquad cdq - cdq[4] = \lambda \cdot (cdq^{*} - cdq[4]) + u$$

$$(3\text{-}3) \qquad cdq^{*} = b_1 \cdot ydq + b_2 \cdot ydq \cdot rrq[\ ] + b_3 \ ,$$

where "*" characterizes planned values, [ ] gives the lag and "q" emphasizes the use of quarterly data.

(2) and (3) imply

$$(3\text{-}4) \qquad \Delta^4 \ cdq = \lambda \cdot b_1 \cdot ydq + \lambda \cdot b_2 \cdot ydq \cdot rrq[] + \lambda \cdot b_3$$
$$\lambda \cdot cdq[4] + u$$

We start out by estimating (4) with a zero lag for rrq (Table 20). The Jarque-Bera and especially the outlier test statistic (Table 21 and 22) reflect the enormous increase in demand for durables in the fourth quarters of 1972 and 1977 due to announced changes in tax laws. There is an offsetting effect in 1978.4 (see parameter b_3 in Table 23), which however is too small to cancel out with the 1977.4 increase (see the F-Test in Table 24), or to be visible in the yearly data analysed in subsection a.

Because of lagged endogenous variables, the range of test procedures is somewhat restricted for the present problem. We first tested for autocorrelation among the error terms by having the $r_j^{(e)}$'s printed for j=1,...,12 (compare p. 60). The results are in Table 25, indicating that the error process can certainly not be viewed as white noise.

Another explanation for Table 25 might be a misspecification of the adjustment process. We therefore tried various lags for ydq, rrq and cdq, with one attempt reproduced in Table 26. ydq[1], cdq[1] and ydq·rrq turn out to be insignificant (see the F-test in Table 27), which in particular led us to conclude that cdq^* might be better explained by rrq[1]. Since this still does not remove first order autocorrelation among the errors, we view this as intrinsic to the error process and supplement (2) and (3) by

$$(3-5) \qquad u = \rho u[1] + \varepsilon.$$

Table 28 gives the results of estimating this model via the Hildreth-Lu procedure. We arrive at the conclusion that consumption of durables in Austria with quarterly data can be explained by the following 3-equation system:

$$(3-2^*) \qquad \Delta^4 cdq = .43 \cdot (cdq^* - cdq[4]) + u$$

$$(3-3^*) \qquad cdq^* = .17 \cdot ydq - 0.004 \cdot ydq \cdot rrq[1] - 4.59$$

$$(3-5^*) \qquad u = .44 \cdot u[1] + \varepsilon.$$

```
---> *t,e 66.1:82.4
Test Processor terminated
 OK
---> *o
IAS-SYSTEM Estimation Processor
Dependent variable of the equation ?
---> cdq-cdq[4]
Explanatory variables of the equation ?
---> cdq[4]
---> ydq
---> ydq*rrq
---> *


OLS   Estimation


      List of Labels


      CDQ              Durable Consumption/real P76
      YDQ              Disposable Income/real P76
      Var1             YDQ*RRQ
      CONST            Constant Term



=============================================================================
 DEP. VARIABLE:  CDQ-CDQ[4]                         I R2   .299 I R2C   .266
-----------------------------------------------------------------------------
 Nr.I Predetermined Variables        I Est. Coeff.I St. Dev.  I   t   I BC %
-----------------------------------------------------------------------------
    I                                I            I           I       I
 B1 I CDQ[4]                         I    -.53113 I    .10759 I  4.94 I 45.8
    I                                I            I           I       I
 B2 I YDQ                            I     .08875 I    .02095 I  4.24 I 42.8
    I                                I            I           I       I
 B3 I Var1                           I    -.00218 I    .00096 I  2.27 I 11.4
    I                                I            I           I       I
 B4 I CONST                          I   -2.17399 I   1.13104 I  1.92 I   .0
    I                                I            I           I       I
-----------------------------------------------------------------------------
 SE     1.32838  I  MAPE     91.25  I 66Q1 -82Q4 I DW  1.856 I RHO(1)    .07
=============================================================================
```

Table 20

```
---> **normal




****************************************************************************

            Jarque-Bera Test for Normality of Residuals
            -------------------------------------------

            H0: Residuals are normally distributed
            H1: Residuals are not normally distributed

              Sum of residuals                    .000
              Sum of residuals**2                1.661
              Sum of residuals**3                5.725
              Sum of residuals**4               45.651

            Value of Jarque-Bera Statistic:    601.360
            Under H0: Chi-square(2)

****************************************************************************
```

Table 21

```
---> **outlie

*******************************************************************************

       Plot-Diagram of t-statistics of Outlier Coefficients
       ------------------------------------------------------

       =========================================================
        Period  I  t-value   I      * ... t-statistics         I
       ---------------------------------------------------------
           :             :
        1972Q1  I       .342 I          *                      I
        1972Q2  I       .443 I          *                      I
        1972Q3  I       .295 I          *                      I
        1972Q4  I      2.810 I                 *               I
        1973Q1  I      -.522 I        *                        I
        1973Q2  I       .022 I         *                       I
        1973Q3  I       .000 I         *                       I
        1973Q4  I      -.137 I         *                       I
        1974Q1  I      -.633 I       *                         I
        1974Q2  I      -.487 I        *                        I
        1974Q3  I       .048 I         *                       I
        1974Q4  I       .460 I          *                      I
        1975Q1  I      -.222 I        *                        I
        1975Q2  I      -.767 I       *                         I
        1975Q3  I      -.568 I        *                        I
        1975Q4  I      1.641 I             *                   I
        1976Q1  I      -.326 I        *                        I
        1976Q2  I      -.366 I        *                        I
        1976Q3  I      -.344 I        *                        I
        1976Q4  I       .745 I           *                     I
        1977Q1  I       .304 I          *                      I
        1977Q2  I       .091 I         *                       I
        1977Q3  I      1.122 I            *                    I
        1977Q4  I      8.077 I                               * I
        1978Q1  I     -1.801 I    *                            I
        1978Q2  I     -1.000 I      *                          I
        1978Q3  I     -1.224 I      *                          I
        1978Q4  I     -3.236 I *                               I
        1979Q1  I       .562 I           *                     I
        1979Q2  I      -.050 I         *                       I
        1979Q3  I      -.454 I        *                        I
        1979Q4  I      -.431 I        *                        I
        1980Q1  I      -.624 I       *                         I
        1980Q2  I      -.669 I       *                         I
        1980Q3  I      -.538 I        *                        I
        1980Q4  I      -.378 I        *                        I
        1981Q1  I     -1.012 I      *                          I
        1981Q2  I      -.293 I        *                        I
        1981Q3  I      -.285 I        *                        I
        1981Q4  I       .056 I         *                       I
        1982Q1  I       .057 I         *                       I
        1982Q2  I      -.074 I         *                       I
        1982Q3  I       .003 I         *                       I
        1982Q4  I       .000 I         *                       I
       =========================================================


            MAX ABS(t-value) at 1977Q4      8.077
            Significance Points:   see IAS-Manual
```

Table 22

```
---> *o
IAS-SYSTEM Estimation Processor
Dependent variable of the equation ?
---> cdq-cdq[4]
Explanatory variables of the equation ?
---> dtp724
---> dtp774
---> dtp774[4]
---> cdq[4]
---> ydq
---> ydq*rrq
---> *


OLS   Estimation


      List of Labels


      CDQ            Durable Consumption/real P76
      DTP724         Dummy Tax-Policy 1972.4
      DTP774         Dummy Tax-Policy 1977.4
      YDQ            Disposable Income/real P76
      Var1           YDQ*RRQ
      CONST          Constant Term
```

```
===========================================================================
 DEP. VARIABLE:  CDQ-CDQ[4]                          I R2    .763 I R2C    .740
---------------------------------------------------------------------------
 Nr.I Predetermined Variables            I Est. Coeff.I St. Dev.  I   t   I BC %
---------------------------------------------------------------------------
    I                                    I            I           I       I
 B1 I DTP724                             I    3.61235 I    .81746 I  4.42 I  8.1
    I                                    I            I           I       I
 B2 I DTP774                             I    7.45657 I    .84897 I  8.78 I 16.8
    I                                    I            I           I       I
 B3 I DTP774[4]                          I   -2.78846 I   1.13828 I  2.45 I  6.3
    I                                    I            I           I       I
 B4 I CDQ[4]                             I    -.51445 I    .09223 I  5.58 I 32.7
    I                                    I            I           I       I
 B5 I YDQ                                I     .08011 I    .01592 I  5.03 I 28.5
    I                                    I            I           I       I
 B6 I Var1                               I    -.00196 I    .00060 I  3.28 I  7.5
    I                                    I            I           I       I
 B7 I CONST                              I   -1.66867 I    .72999 I  2.29 I   .0
    I                                    I            I           I       I
---------------------------------------------------------------------------
 SE       .79095  I  MAPE     109.23  I 66Q1 -82Q4 I DW   1.428 I RHO(1)    .29
===========================================================================
```

Table 23

```
---> **gf 1
Insert restrictions for
B1     B2      B3      B4      B5      R
---> 0,1,1,0,0,0


*******************************************************************************

            General F-Test
            --------------

            H0:     B1      B2      B3      B4      B5      R
                    .00     1.00    1.00    .00     .00     .00

            H1: Restrictions under H0 are not valid

                 OLS-coefficient      Restricted  OLS
                    Estimates            Estimates

            B1         3.61235           3.40551
            B2         7.45657           5.66256
            B3        -2.78846          -5.66256
            B4         -.51445           -.33077
            B5          .08011            .05302
            B6         -.00196           -.00196
            B7        -1.66867          -1.66867

            Value of Test-Statistic:     96.318
            Under H0: F( 1, 61)

*******************************************************************************
```

Table 24

```
---> **lm 12


************************************************************************

          LM-Test for simple Autocorrelation
          ----------------------------------

          Model: u=rho*u[j]+eps
             H0: rho.EQ.0
             H1: rho.NE.0

          Lag(j)     Value of Test-Statistic

            1                 2.621
            2                  .307
            3                  .682
            4                  .349
            5                  .520
            6                  .175
            7                  .030
            8                  .384
            9                 1.645
           10                  .903
           11                 1.651
           12                  .162

          Under H0: N(0,1)
************************************************************************
```

Table 25

```
---> *o
IAS-SYSTEM Estimation Processor
Dependent variable of the equation ?
---> cdq-cdq[4]
Explanatory variables of the equation ?
---> dtp724
---> dtp774
---> dtp774[4]
---> ydq[1]
---> cdq[1]
---> ydq*rrq
---> cdq[4]
---> ydq
---> ydq*rrq[1]
---> *

OLS   Estimation


        List of Labels


        CDQ             Durable Consumption/real P76
        DTP724          Dummy Tax-Policy 1972.4
        DTP774          Dummy Tax-Policy 1977.4
        YDQ             Disposable Income/real P76
        Var1            YDQ*RRQ
        Var2            YDQ*RRQ[1]
        CONST           Constant Term

=============================================================================
 DEP. VARIABLE:  CDQ-CDQ[4]                            I R2   .786 I R2C   .753
-----------------------------------------------------------------------------
 Nr.I Predetermined Variables           I Est. Coeff.I St. Dev.  I   t   I BC %
-----------------------------------------------------------------------------
    I                                   I            I           I       I
 B1 I DTP724                            I    3.61037 I    .79928 I  4.52 I  7.2
    I                                   I            I           I       I
 B2 I DTP774                            I    7.44326 I    .84291 I  8.83 I 14.9
    I                                   I            I           I       I
 B3 I DTP774[4]                         I   -2.67252 I   1.12828 I  2.37 I  5.3
    I                                   I            I           I       I
 B4 I YDQ[1]                            I    -.00643 I    .02168 I   .30 I  2.0
    I                                   I            I           I       I
 B5 I CDQ[1]                            I    -.04406 I    .08049 I   .55 I  2.4
    I                                   I            I           I       I
 B6 I Var1                              I    -.00077 I    .00100 I   .77 I  2.6
    I                                   I            I           I       I
 B7 I CDQ[4]                            I    -.53556 I    .09353 I  5.73 I 30.2
    I                                   I            I           I       I
 B8 I YDQ                               I     .09527 I    .02163 I  4.40 I 30.1
    I                                   I            I           I       I
 B9 I Var2                              I    -.00162 I    .00098 I  1.65 I  5.4
    I                                   I            I           I       I
 B10I CONST                             I   -1.70226 I    .74185 I  2.29 I   .0
    I                                   I            I           I       I
-----------------------------------------------------------------------------
 SE      .77042  I  MAPE    114.07  I 66Q1 -82Q4 I DW   1.271 I RHO(1)    .36
=============================================================================
```

Table 26

```
---> **f
Insert parameter restrictions to be tested
---> B4=0,B5=0,B6=0



****************************************************************************

            F-Test
            ------

            H0: B4:0,B5:0,B6:0
            H1: At least one restriction is not valid

            Value of F-Statistic:      1.097
            Under H0: F( 3, 58)

****************************************************************************
```

Table 27

```
---> *t,e 66.2:82.4
 OK
---> *o,h
IAS-SYSTEM Estimation Processor
Dependent variable of the equation ?
---> cdq-cdq[4]
Explanatory variables of the equation ?
---> dtp724
---> dtp774
---> dtp774[4]
---> cdq[4]
---> ydq
---> ydq*rrq[1]
---> *

OLS   Estimation


      List of Labels


      CDQ              Durable Consumption/real P76
      DTP724           Dummy Tax-Policy 1972.4
      DTP774           Dummy Tax-Policy 1977.4
      YDQ              Disposable Income/real P76
      Var1             YDQ*RRQ[1]
      CONST            Constant Term



      Hildreth-Lu Estimation: RHO =   .44000


==============================================================
 DEP. VARIABLE:  CDQ-CDQ[4]                  I R2   .819 I R2C   .801
--------------------------------------------------------------
 Nr.I Predetermined Variables     I Est. Coeff.I St. Dev.  I   t   I BC %
--------------------------------------------------------------
    I                             I            I           I       I
 B1 I DTP724                      I    3.68671 I    .67430 I  5.47 I  7.7
    I                             I            I           I       I
 B2 I DTP774                      I    7.35088 I    .69541 I 10.57 I 15.4
    I                             I            I           I       I
 B3 I DTP774[4]                   I   -3.63614 I    .99924 I  3.64 I  7.6
    I                             I            I           I       I
 B4 I CDQ[4]                      I    -.42488 I    .08384 I  5.07 I 29.5
    I                             I            I           I       I
 B5 I YDQ                         I     .07334 I    .01652 I  4.44 I 34.9
    I                             I            I           I       I
 B6 I Var1                        I    -.00177 I    .00073 I  2.42 I  4.8
    I                             I            I           I       I
 B7 I CONST                       I   -2.01917 I    .98405 I  2.05 I   .0
    I                             I            I           I       I
--------------------------------------------------------------
 SE     .72360  I  MAPE     72.43 I 66Q2 -82Q4 I DW   1.968 I RHO(1)   .01
==============================================================
```

Table 28

c) Determination of working hours

We next discuss a model that was used in a recent simulation on the effects of shortening the legal work week (Maurer and Pichelmann, 1983). A major problem here is splitting employment as measured by hours worked into its components (i) hours worked per worker per week and (ii) number or workers employed.

Under profit maximization, one has

$$(3\text{-}6) \qquad F_N(N,K) = \frac{W}{p}$$

where
F = production function
N = hours worked per year
K = capital
W = hourly wage
p = output price
y = output quantity

Assuming further a CES-production function, this gives

$$(3\text{-}7) \qquad N = \gamma \cdot \left(\frac{W}{p}\right)^{\sigma} \cdot y, \quad \gamma > 0, \quad \sigma < 0 \ ,$$

where N can be expressed as

$$(3\text{-}8) \qquad N = L \cdot H_W \cdot 52$$

with
L = average level of employment
H_W = hours worked per week.

This implies

(3-9) $$L^{*} = \gamma^{*} \cdot (\frac{W}{p})^{\sigma} \cdot \frac{y}{H_W} ,$$

where L^{*} might be viewed as the profit-maximizing employment level, given y, W, p and H_w. The model is closed by adding two more equations to (9):

(3-10) $$(\frac{L}{L[1]} = (\frac{L^{*}}{L[1]})^{\rho} \quad , \quad \rho>0$$

(3-11) $$H_W = f(H_l, BC) ,$$

where ρ = adjustment factor
H_l = legal working time, hours per week
BC = business cycle variable.

For BC, we used GDP/GDPS, where GDP = gross domestic product and GDPS is the trend value of GDP.

When BC>1, the labour market will be tight and people will work more hours per week, whereas with BC<1, opportunities to work overtime will be scarce and the working hours shortened.

We now show how the IAS-SYSTEM test processor can be used to find an adequate specification of (11).

Consider first a logarithmic specification of (11):

$$(3\text{-}12) \qquad \ln H_W = \ln \gamma + \Sigma_{i=0}^{2} \rho_i \ln H_1[i] + \psi \ln BC + u$$

Table 29 reports the OLS-estimates for this equation, using yearly data from 1966-1981, after dropping the constant, which turned out to be insignificant.

Again, the Durbin-Watson statistic points to misspecification of some kind. Because the estimate for the first order correlation of the errors was also very large, we reestimated (12) using first differences. The results are in Table 30. They lend some support to the hypothesis, which is often advanced recently, that changes in H_1 require approximately 2 years to transmit themselves to H_W. This can also be checked by an F-test of H_0: $B_1+B_2+B_3=1$ and $B_3=0$ (see Table 31). Table 32 presents the results of estimating (12) with these restrictions imposed a priori.

We first check this final equation for stability of the regression parameters. Since one variable (Δ ln NAZ - Δ ln NAZ[1]) is zero for 66-69, the System cannot calculate the Quandt and Chow tests. The Cusum and Cusum of squares tests (reproduced in Table 33 and 34) give no reason to worry. The same applies to various tests for autocorrelation and homoscedasticity of the error terms (Table 35-37). The outlier test (Table 38, lower part) points to a possible outlier in 1980, for which however we do not have an economic interpretation. Since the inclusion of a dummy for 1980 does not much affect the estimates of the remaining parameters, we accept Table 32 as the final empirical version of the working time function (11).

```
---> *t,e 66:81
Test Processor terminated
 OK
---> *o,c
IAS-SYSTEM Estimation Processor
Dependent variable of the equation ?
---> ln(hbu)
Explanatory variables of the equation ?
---> ln(naz)
---> ln(naz[1])
---> ln(naz[2])
---> ln(gdp/gdps)
---> *
```

```
OLS   Estimation


      List of Labels


      HBU               Average Working Time/Hours per Week
      NAZ               Legal Working Time/Hours per Week
      Var1              ln(GDP/GDPS)



=============================================================================
 DEP. VARIABLE:  ln(HBU)                                I R2    .982 I R2C    .977
-----------------------------------------------------------------------------
 Nr.I Predetermined Variables         I Est. Coeff.I St. Dev.  I    t    I BC %
-----------------------------------------------------------------------------
    I                                 I            I           I         I
 B1 I ln(NAZ)                         I      .50928 I    .11679 I  4.36  I 48.6
    I                                 I            I           I         I
 B2 I ln(NAZ[1])                      I      .28317 I    .14968 I  1.89  I 27.7
    I                                 I            I           I         I
 B3 I ln(NAZ[2])                      I      .18914 I    .11451 I  1.65  I 18.5
    I                                 I            I           I         I
 B4 I Var1                            I      .20741 I    .14788 I  1.40  I  5.2
    I                                 I            I           I         I
-----------------------------------------------------------------------------
 SE       .00711  I   MAPE          .14  I 66    -81    I DW    .737 I RHO(1)    .69
=============================================================================
```

Table 29

```
---> *o,c
Test Processor terminated
IAS-SYSTEM Estimation Processor
Dependent variable of the equation ?
---> ln(hbu/hbu[1])
Explanatory variables of the equation ?
---> ln(naz/naz[1])
---> ln(naz[1]/naz[2])
---> ln(naz[2]/naz[3])
---> ln(gdp/gdps)-ln(gdp[1]/gdps[1])
---> *


OLS   Estimation


      List of Labels


      HBU               Average Working Time/Hours per Week
      NAZ               Legal Working Time/Hours per Week
      Var1              ln(GDP/GDPS)-ln(GDP[1]/GDPS[1])



==============================================================================
 DEP. VARIABLE:  ln(HBU/HBU[1])                          I R2    .838 I R2C    .798
------------------------------------------------------------------------------
 Nr.I Predetermined Variables            I Est. Coeff.I St. Dev.  I    t    I BC %
------------------------------------------------------------------------------
    I                                    I            I           I         I
 B1 I ln(NAZ/NAZ[1])                     I     .60137 I    .08048 I  7.47   I 53.0
    I                                    I            I           I         I
 B2 I ln(NAZ[1]/NAZ[2])                  I     .27444 I    .07952 I  3.45   I 24.2
    I                                    I            I           I         I
 B3 I ln(NAZ[2]/NAZ[3])                  I     .05321 I    .07722 I   .69   I  4.7
    I                                    I            I           I         I
 B4 I Var1                               I     .17972 I    .07993 I  2.25   I 18.1
    I                                    I            I           I         I
------------------------------------------------------------------------------
 SE       .00533  I  MAPE       11.14  I 66    -81    I DW   1.607 I RHO(1)    .16
==============================================================================
```

Table 30

```
---> **gf 2
Insert restrictions for
B1     B2      B3      B4       R
---> 1,1,1,0,1
---> 0,0,1,0,0


************************************************************************

           General F-Test
           --------------

           H0:      B1       B2       B3       B4        R
                  1.00     1.00     1.00      .00     1.00
                   .00      .00     1.00      .00      .00

           H1: Restrictions under H0 are not valid

                OLS-coefficient     Restricted  OLS
                    Estimates           Estimates

           B1           .60137             .66835
           B2           .27444             .33165
           B3           .05321             .00000
           B4           .17972             .18242

           Value of Test-Statistic:       .796
           Under H0: F( 2, 12)

************************************************************************
```

Table 31

```
---> *o,c
IAS-SYSTEM Estimation Processor
Dependent variable of the equation ?
---> ln(hbu/hbu[1])-ln(naz[1]/naz[2])
Explanatory variables of the equation ?
---> ln(naz/naz[1])-ln(naz[1]/naz[2])
---> ln(gdp/gdps)-ln(gdp[1]/gdps[1])
---> *
```

```
OLS   Estimation


      List of Labels


      Var1           ln(HBU/HBU[1])-ln(NAZ[1]/NAZ[2])
      Var2           ln(NAZ/NAZ[1])-ln(NAZ[1]/NAZ[2])
      Var3           ln(GDP/GDPS)-ln(GDP[1]/GDPS[1])


==========================================================================
 DEP. VARIABLE:  Var1                                 I R2   .935 I R2C   .930
--------------------------------------------------------------------------
 Nr.I Predetermined Variables         I Est. Coeff.I St. Dev.  I   t   I BC %
--------------------------------------------------------------------------
    I                                 I            I           I       I
 B1 I Var2                            I     .66835 I    .05767 I 11.59 I 83.3
    I                                 I            I           I       I
 B2 I Var3                            I     .18242 I    .07873 I  2.32 I 16.7
    I                                 I            I           I       I
--------------------------------------------------------------------------
 SE       .00526  I  MAPE       9.83  I 66    -81    I DW  1.716 I RHO(1)    .10
==========================================================================
```

Table 32

```
---> **cusum,d 5
Insert regression parameters to be printed
---> B1,B2
How many dummies are present in the regression (max 2 allowed) ?
---> 1

*****************************************************************************

                 Table of Recursive Regression Parameters
                 ----------------------------------------

              B1        B2
 -66        .0000     .0000
 -67        .0000     .5167
 -68        .0000     .3861
 -69        .0000     .2700
 -70        .6364     .2700
 -71        .7075     .3613
 -72        .6727     .2193
 -73        .6835     .2465
 -74        .6838     .2447
 -75        .6610     .2125
 -76        .6594     .2121
 -77        .6692     .1796
 -78        .6717     .1713
 -79        .6770     .1536
 -80        .6811     .1401
 -81        .6683     .1824

                  Regression Constancy - CUSUM Test
                  ---------------------------------

 ********************************************************************
 I TIME  I   VALUE OF THE TEST STATISTIC     I   5% I  UPPER BOUND  I
 ********************************************************************
 I -67   I                   -.539           I   0  I     4.054     I
 I -68   I                   1.219           I   0  I     4.561     I
 I -69   I                    .248           I   0  I     5.067     I
 I -71   I                    .810           I   0  I     5.574     I
 I -72   I                   1.692           I   0  I     6.081     I
 I -73   I                   2.212           I   0  I     6.587     I
 I -74   I                   2.148           I   0  I     7.094     I
 I -75   I                   2.867           I   0  I     7.601     I
 I -76   I                   2.806           I   0  I     8.108     I
 I -77   I                   1.721           I   0  I     8.614     I
 I -78   I                   1.946           I   0  I     9.121     I
 I -79   I                   1.341           I   0  I     9.628     I
 I -80   I                   -.819           I   0  I    10.135     I
 I -81   I                  -2.055           I   0  I    10.641     I
 ********************************************************************
```

Table 33

```
---> **cusum2,d 5
Insert regression parameters to be printed
---> B1,B2
Insert table significance value for test (IAS-Manual: C( 6.0)):
---> .4
How many dummies are present in the regression (max 2 allowed) ?
---> 1

***********************************************************************

              Table of Recursive Regression Parameters
              ----------------------------------------

           B1        B2
-66      .0000     .0000
-67      .0000     .5167
-68      .0000     .3861
-69      .0000     .2700
-70      .6364     .2700
-71      .7075     .3613
-72      .6727     .2193
-73      .6835     .2465
-74      .6838     .2447
-75      .6610     .2125
-76      .6594     .2121
-77      .6692     .1796
-78      .6717     .1713
-79      .6770     .1536
-80      .6811     .1401
-81      .6683     .1824

            Regression Constancy - Cusum of Squares Test
            --------------------------------------------

***************************************************************
I TIME I LOWER BOUND I VALUE OF TEST STATISTIC I UPPER BOUND I  5% I
***************************************************************
I 67   I    -.3286   I         .0208           I     .4714   I  0  I
I 68   I    -.2571   I         .2417           I     .5429   I  0  I
I 69   I    -.1857   I         .3091           I     .6143   I  0  I
I 71   I    -.1143   I         .3317           I     .6857   I  0  I
I 72   I    -.0429   I         .3872           I     .7571   I  0  I
I 73   I     .0286   I         .4065           I     .8286   I  0  I
I 74   I     .1000   I         .4068           I     .9000   I  0  I
I 75   I     .1714   I         .4437           I     .9714   I  0  I
I 76   I     .2429   I         .4439           I    1.0429   I  0  I
I 77   I     .3143   I         .5280           I    1.1143   I  0  I
I 78   I     .3857   I         .5316           I    1.1857   I  0  I
I 79   I     .4571   I         .5578           I    1.2571   I  0  I
I 80   I     .5286   I         .8909           I    1.3286   I  0  I
I 81   I     .6000   I        1.0000           I    1.4000   I  0  I
***************************************************************
```

Table 34

```
---> **ar 3

******************************************************************************

          LM-Test for simple Autocorrelation
          ----------------------------------

          Model: u=rho*u[j]+eps
             H0: rho.EQ.0
             H1: rho.NE.0

          Lag(j)     Aut. coeff.     Value of Test-Statistic

            1            .095                  .380
            2            .178                  .713
            3            .224                  .895

          Under H0: N(0,1)

  Warning: Test statistic valid only without lagged endogenous variables
******************************************************************************
```

Table 35

```
---> **gq

**************************************************************************

          Goldfeld-Quandt Test for Heteroscedasticity
          -------------------------------------------

          H0: Residuals are homoscedastic
          H1: Residuals are heteroscedastic

          Value of Test-Statistic:      .743
          Under H0: F( 6,  6)

     Number of observations deleted in the middle of the sample:   0

**************************************************************************
```

```
---> **gq,s
Insert position of variable according to which the sample is to be reordered
---> 2

**************************************************************************

          Goldfeld-Quandt Test for Heteroscedasticity
          -------------------------------------------

          H0: Residuals are homoscedastic
          H1: Residuals are heteroscedastic

          Value of Test-Statistic:     3.642
          Under H0: F( 6,  6)

     Number of observations deleted in the middle of the sample:   0

     Observations ordered acc. to increasing values of variable:   2

**************************************************************************
```

Table 36

```
---> **white

****************************************************************************

            White's Test for General Heteroscedasticity
            -------------------------------------------

            H0: Residuals are homoscedastic
            H1: Residuals are heteroscedastic

            Value of Test-Statistic:     3.110
            Under H0: Chi-square ( 4)

****************************************************************************
```

```
---> **atv

****************************************************************************

            White's Heteroscedasticity adjusted t-values
            --------------------------------------------

            Parameters      t-values       adj. t-values

               B1             11.590             18.901
               B2              2.317              3.051

****************************************************************************
```

Table 37

```
---> **normal

***************************************************************************

              Jarque-Bera Test for Normality of Residuals
              -------------------------------------------

              H0: Residuals are normally distributed
              H1: Residuals are not normally distributed

                Sum of residuals                       -.001
                Sum of residuals**2                     .000
                Sum of residuals**3                     .000
                Sum of residuals**4                     .000

              Value of Jarque-Bera Statistic:            .291
              Under H0: Chi-square(2)

***************************************************************************

---> **outlie

***************************************************************************

        Plot-Diagram of t-statistics of Outlier Coefficients
        ----------------------------------------------------

        ======================================================
         Period  I  t-value  I      * ... t-statistics       I
        ------------------------------------------------------
         1966    I     -.176 I                  *            I
         1967    I    -1.308 I          *                    I
         1968    I     1.615 I                             * I
         1969    I     -.738 I              *                I
         1970    I      .736 I                       *       I
         1971    I      .927 I                         *     I
         1972    I      .294 I                    *          I
         1973    I      .797 I                        *      I
         1974    I      .075 I                   *           I
         1975    I      .508 I                      *        I
         1976    I     -.040 I                  *            I
         1977    I    -1.083 I          *                    I
         1978    I      .260 I                    *          I
         1979    I     -.698 I             *                 I
         1980    I    -2.611 I *                             I
         1981    I    -1.262 I         *                     I
        ======================================================

              MAX ABS(t-value) at 1980          2.611
              Significance Points:   see IAS-Manual

***************************************************************************
```

Table 38

d) Demand for labour in the Austrian building industry

In Austria, there has been some debate recently on the shortrun labour demand effects of demand management in the building and construction industries. Because of institutional peculiarities, this sector of the economy does not fit in easily into a sophisticated neoclassical framework and is perhaps best modelled by a comparably simple equation (see Munduch, 1983). In the context of such a simple formal model, the debate may be viewed as centering on which of the following equations gives a better description of labour demand.

$$(3\text{-}13) \qquad L_t = \gamma \cdot Y_t^{\alpha} \cdot e^{-\psi t}, \quad 0<\alpha<1$$

or

$$(3\text{-}14) \qquad L_t = \gamma \cdot Y_t \cdot e^{-\psi t},$$

where L_t = labour demand

ψ = rate of growth of productivity

Y_t = real output

Both formulations imply nonsubstitutability between capital and labour, and the only difference of opinion is about the numerical value of α , which governs the short-run effects of demand management. Below we seek to solve this problem empirically, by estimating the following models:

(3-13a) $\Delta \ln L = \alpha \Delta \ln y - \psi$

(3-14a) $(\frac{L}{L[1]}) = (\frac{L^{*}}{L[1]})^{\rho} = (\frac{\gamma y e^{-\psi t}}{L[1]})^{\rho}$

where (14a) may also be written

(3-14b) $\Delta \ln L_t = \rho \ln \gamma + \rho \ln (y/L[1]) - \rho\psi t$.

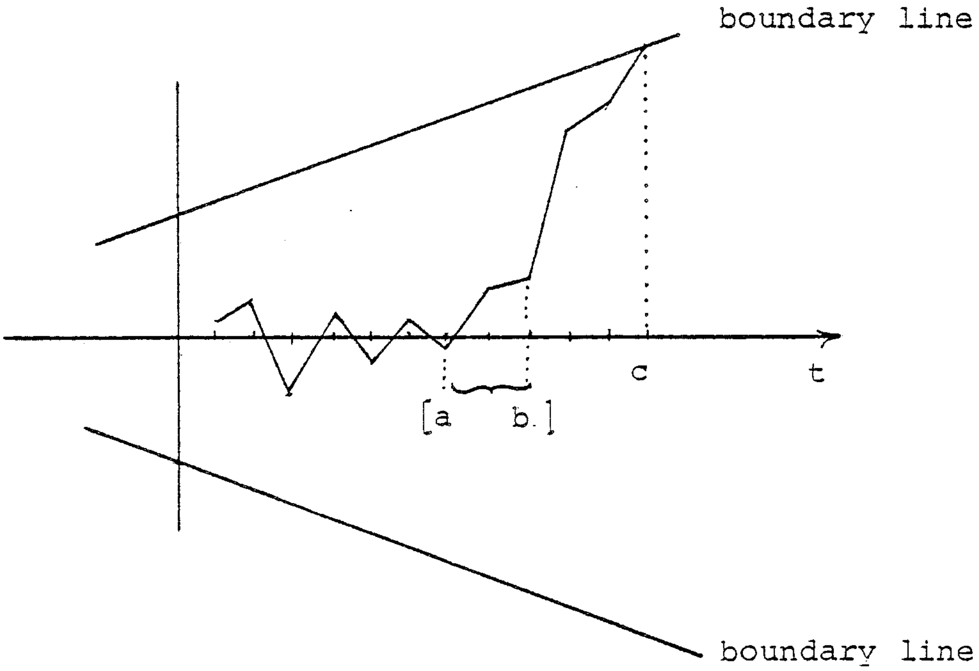
Table 39 gives the OLS-estimates of (13a) using yearly data for the period 1966-1980.

From the Durbin-Watson, Chow, Quandt and Cusum statistics (Table 40 and 41) it is clear that there is some structural break in the regression, which the Chow test locates at 1972. While the Cusum-statistic is not formally significant, its behaviour from 1972 on nevertheless strongly suggests that a structural break has occurred (in general, the time point of a structural break will preceed the time point were the Cusum-statistic crosses the critical line; see Figure 3 next page).

The most plausible explanation for the change of regime in 1972 is a fall in productivity growth. Adding a dummy to take care of this and reestimating (see Table 42) indicates a fall in ψ from 5.1 % to 1.1 %. α is estimated at .77, which is less than unity, but not significantly so (see the F-test in Table 43). Also, none of the other tests casts significant doubt on the equation (Tables 44-48).

The investigation of (14b) parallels that of (13a). Table 49 presents estimation results with the dummy for a change in ψ already included. B_4 $(=\rho)$ is close to unity and the equation likewise passes all tests (Tables 50-52). We therefore conclude that the data do not permit to reject the hypothesis that α equals unity.

FIGURE 3
Time path of Cusum statistic



[a,b] period of structural change
c crossing-point

```
 ---> *t,e 66:80
  OK
 ---> *o
 IAS-SYSTEM Estimation Processor
 Dependent variable of the equation ?
 ---> ln(bu13/bu13[1])
 Explanatory variables of the equation ?
 ---> ln(qnp13r/qnp13r[1])
 ---> *

OLS   Estimation


      List of Labels


      BU13            Employment/Construction Sector
      QNP13R          Real Output/Construction Sector  P76
      CONST           Constant Term


=========================================================================
 DEP. VARIABLE:  ln(BU13/BU13[1])                    I R2    .384 I R2C    .337
-------------------------------------------------------------------------
 Nr.I Predetermined Variables           I Est. Coeff.I St. Dev.  I   t   I BC %
-------------------------------------------------------------------------
    I                                   I            I           I       I
 B1 I ln(QNP13R/QNP13R[1])              I     .46817 I    .16433 I  2.85 I100.0
    I                                   I            I           I       I
 B2 I CONST                             I    -.01636 I    .00811 I  2.02 I   .0
    I                                   I            I           I       I
-------------------------------------------------------------------------
 SE       .02245  I  MAPE       19.36  I 66    -80    I DW   1.096 I RHO(1)    .45
=========================================================================
```

Table 39

```
---> **quandt

****************************************************************************

       Plot Diagram of Quandt-Ratios
       -----------------------------

       ========================================================
        Period  I   Ratio    I     * ... Quandt Ratios        I
       --------------------------------------------------------
        1968    I     -5.060 I               *                I
        1969    I     -3.797 I                      *         I
        1970    I     -4.526 I                  *             I
        1971    I     -7.426 I *                              I
        1972    I     -3.756 I                      *         I
        1973    I     -2.402 I                              * I
        1974    I     -3.834 I                      *         I
        1975    I     -3.682 I                       *        I
        1976    I     -2.494 I                              * I
        1977    I     -3.832 I                      *         I
       ========================================================

                 MIN (Quandt-Ratios) at  1971
                 New regime starting at  1972

****************************************************************************


---> **chow 72

****************************************************************************

            Chow-Test for Parameter Stability
            ---------------------------------

            H0: All parameters are stable over:  1966    - 1980
            H1: At least one parameter changes at:         1972

            Value of Chow-Statistic:      9.279
            Under H0: F( 2, 11)

****************************************************************************
```

Table 40

```
---> **cusum 5
Insert regression parameters to be printed
---> B1,B2

*****************************************************************************

                 Table of Recursive Regression Parameters
                 ----------------------------------------

           B1        B2
 -67     .7825    -.0513
 -68     .9528    -.0682
 -69     .7694    -.0517
 -70     .7369    -.0479
 -71     .6930    -.0462
 -72     .7276    -.0417
 -73     .6798    -.0325
 -74     .6850    -.0330
 -75     .6283    -.0292
 -76     .5646    -.0245
 -77     .5503    -.0216
 -78     .4683    -.0164
 -79     .4626    -.0160
 -80     .4682    -.0164


                   Regression Constancy - CUSUM Test
                   ---------------------------------

**********************************************************************
I TIME  I   VALUE OF THE TEST STATISTIC    I  5% I  UPPER BOUND   I
**********************************************************************
I -68   I                     -.706        I  0  I     3.944      I
I -69   I                      .332        I  0  I     4.470      I
I -70   I                      .778        I  0  I     4.996      I
I -71   I                      .628        I  0  I     5.521      I
I -72   I                     2.509        I  0  I     6.047      I
I -73   I                     4.639        I  0  I     6.573      I
I -74   I                     4.573        I  0  I     7.099      I
I -75   I                     4.912        I  0  I     7.625      I
I -76   I                     5.700        I  0  I     8.151      I
I -77   I                     6.855        I  0  I     8.677      I
I -78   I                     7.868        I  0  I     9.202      I
I -79   I                     7.986        I  0  I     9.728      I
I -80   I                     7.865        I  0  I    10.254      I
**********************************************************************
```

Table 41

```
---> *o
IAS-SYSTEM Estimation Processor
Dependent variable of the equation ?
---> ln(bu13/bu13[1])
Explanatory variables of the equation ?
---> d7290
---> ln(qnp13r/qnp13r[1])
---> *


OLS   Estimation


      List of Labels


      BU13             Employment/Construction Sector
      D7290            Dummy 1972-1990
      QNP13R           Real Output/Construction Sector  P76
      CONST            Constant Term


=============================================================================
DEP. VARIABLE:  ln(BU13/BU13[1])                      I R2    .762 I R2C    .723
-----------------------------------------------------------------------------
Nr.I Predetermined Variables             I Est. Coeff.I St. Dev.  I   t    I BC %
-----------------------------------------------------------------------------
   I                                     I            I           I        I
B1 I D7290                               I     .04019 I    .00920 I  4.37  I 41.8
   I                                     I            I           I        I
B2 I ln(QNP13R/QNP13R[1])                I     .77806 I    .12773 I  6.09  I 58.2
   I                                     I            I           I        I
B3 I CONST                               I    -.05116 I    .00953 I  5.37  I   .0
   I                                     I            I           I        I
-----------------------------------------------------------------------------
SE      .01451  I  MAPE      6.51  I 66    -80    I DW  2.256 I RHO(1)   -.14
=============================================================================
```

Table 42

```
---> **f
Insert parameter restrictions to be tested
---> B2=1

****************************************************************************

            F-Test
            ------

            H0: B2=1
            H1: At least one restriction is not valid

            Value of F-Statistic:      3.019
            Under H0: F( 1, 12)

****************************************************************************
```

Table 43

```
---> **cusum,d 5
Insert regression parameters to be printed
---> B1,B2,B3
How many dummies are present in the regression (max 2 allowed) ?
---> 1


******************************************************************************

                   Table of Recursive Regression Parameters
                   ----------------------------------------

            B1        B2        B3
 -67      .0000     .7825    -.0513
 -68      .0000     .9528    -.0682
 -69      .0000     .7694    -.0517
 -70      .0000     .7369    -.0479
 -71      .0000     .6930    -.0462
 -72      .0457     .6930    -.0462
 -73      .0516     .6822    -.0456
 -74      .0390     .7798    -.0513
 -75      .0378     .8244    -.0539
 -76      .0386     .8092    -.0530
 -77      .0401     .8148    -.0533
 -78      .0410     .7568    -.0499
 -79      .0406     .7647    -.0504
 -80      .0402     .7781    -.0512


                      Regression Constancy - CUSUM Test
                      ---------------------------------

 **********************************************************************
 I TIME  I   VALUE OF THE TEST STATISTIC     I   5% I  UPPER BOUND  I
 **********************************************************************
 I -68   I                -1.092             I   0  I     3.831     I
 I -69   I                  .514             I   0  I     4.379     I
 I -70   I                 1.204             I   0  I     4.926     I
 I -71   I                  .972             I   0  I     5.473     I
 I -73   I                 1.547             I   0  I     6.021     I
 I -74   I                 -.651             I   0  I     6.568     I
 I -75   I                -1.108             I   0  I     7.115     I
 I -76   I                 -.726             I   0  I     7.663     I
 I -77   I                 -.229             I   0  I     8.210     I
 I -78   I                  .996             I   0  I     8.757     I
 I -79   I                  .661             I   0  I     9.305     I
 I -80   I                  .097             I   0  I     9.852     I
 **********************************************************************
```

Table 44

```
---> **cusum2,d 5
Insert regression parameters to be printed
--->
Insert table significance value for test (IAS-Manual: C( 5.0)):
---> .422
How many dummies are present in the regression (max 2 allowed) ?
---> 1
```

```
                 Regression Constancy - Cusum of Squares Test
                 --------------------------------------------

************************************************************************
I TIME I LOWER BOUND I VALUE OF TEST STATISTIC I UPPER BOUND I  5% I
************************************************************************
I 68   I    -.3387   I          .0994          I     .5053   I  0  I
I 69   I    -.2553   I          .3144          I     .5887   I  0  I
I 70   I    -.1720   I          .3541          I     .6720   I  0  I
I 71   I    -.0887   I          .3586          I     .7553   I  0  I
I 73   I    -.0053   I          .3862          I     .8387   I  0  I
I 74   I     .0780   I          .7889          I     .9220   I  0  I
I 75   I     .1613   I          .8063          I    1.0053   I  0  I
I 76   I     .2447   I          .8184          I    1.0887   I  0  I
I 77   I     .3280   I          .8390          I    1.1720   I  0  I
I 78   I     .4113   I          .9641          I    1.2553   I  0  I
I 79   I     .4947   I          .9735          I    1.3387   I  0  I
I 80   I     .5780   I         1.0000          I    1.4220   I  0  I
************************************************************************
```

Table 45

```
---> **ar 3



******************************************************************************

           LM-Test for simple Autocorrelation
           ----------------------------------

           Model: u=rho*u[j]+eps
              H0: rho.EQ.0
              H1: rho.NE.0

           Lag(j)     Aut. coeff.     Value of Test-Statistic

             1           -.139                 -.539
             2           -.382                -1.480
             3            .075                  .290

           Under H0: N(0,1)

  Warning: Test statistic valid only without lagged endogenous variables
******************************************************************************
```

Table 46

```
---> **diff



**************************************************************************

    Plosser-Schwert-White Differencing Test for Model Specification
    ---------------------------------------------------------------

          H0: Standard assumptions of OLS-regression are valid
          H1: Model Specification is incorrect

                 OLS-coefficient      First-difference
                    Estimates            Estimates

          B1          .04019               .04561
          B2          .77806               .64542

          Value of Test-Statistic:       1.480
          Under H0: Chi-square ( 2)

**************************************************************************
```

Table 47

```
---> **normal
******************************************************************************

          Jarque-Bera Test for Normality of Residuals
          -------------------------------------------

          H0: Residuals are normally distributed
          H1: Residuals are not normally distributed

            Sum of residuals                     .000
            Sum of residuals**2                  .000
            Sum of residuals**3                  .000
            Sum of residuals**4                  .000

          Value of Jarque-Bera Statistic:          .541
          Under H0: Chi-square(2)

******************************************************************************

---> **outlie

******************************************************************************

      Plot-Diagram of t-statistics of Outlier Coefficients
      -----------------------------------------------------

      =========================================================
       Period   I t-value   I      * ... t-statistics         I
      ---------------------------------------------------------
       1966     I      .024 I                   *             I
       1967     I      .003 I                   *             I
       1968     I    -1.864 I    *                            I
       1969     I     1.448 I                               * I
       1970     I      .793 I                          *      I
       1971     I     -.558 I              *                  I
       1972     I      .391 I                       *         I
       1973     I     1.439 I                               * I
       1974     I    -2.266 I *                               I
       1975     I     -.792 I             *                   I
       1976     I      .103 I                     *           I
       1977     I      .407 I                       *         I
       1978     I     1.405 I                               * I
       1979     I     -.233 I                  *              I
       1980     I     -.548 I               *                 I
      =========================================================


          MAX ABS(t-value) at 1974          2.266
          Significance Points:    see IAS-Manual

******************************************************************************
```

Table 48

```
---> *o
IAS-SYSTEM Estimation Processor
Dependent variable of the equation ?
---> ln(bu13/bu13[1])
Explanatory variables of the equation ?
---> d7290
---> d7290*time
---> time
---> ln(qnp13r/bu13[1])
---> *


OLS   Estimation


      List of Labels


      BU13              Employment/Construction Sector
      D7290             Dummy 1972-1990
      Var1              D7290*TIME
      TIME              Trendvariable
      Var2              ln(QNP13R/BU13[1])
      CONST             Constant Term


===============================================================================
 DEP. VARIABLE:  ln(BU13/BU13[1])                        I R2   .811 I R2C   .736
-------------------------------------------------------------------------------
 Nr.I Predetermined Variables             I Est. Coeff.I St. Dev.  I    t   I BC %
-------------------------------------------------------------------------------
    I                                     I            I           I        I
 B1 I D7290                               I   -3.27199 I    .76358 I  4.29  I 43.2
    I                                     I            I           I        I
 B2 I Var1                                I     .04576 I    .01064 I  4.30  I 46.0
    I                                     I            I           I        I
 B3 I TIME                                I    -.05945 I    .01181 I  5.03  I  6.9
    I                                     I            I           I        I
 B4 I Var2                                I     .98402 I    .17915 I  5.49  I  3.8
    I                                     I            I           I        I
 B5 I CONST                               I    5.75420 I   1.10720 I  5.20  I   .0
    I                                     I            I           I        I
-------------------------------------------------------------------------------
 SE        .01417  I  MAPE       10.09  I 66    -80   I DW   1.657 I RHO(1)    .17
===============================================================================
```

Table 49

```
--->  **cusum,d 5
Insert regression parameters to be printed
---> B1,B2,B3,B4,B5
How many dummies are present in the regression (max 2 allowed) ?
---> 2


****************************************************************************

                Table of Recursive Regression Parameters
                ----------------------------------------

             B1        B2        B3        B4        B5
 -68        .0000     .0000    -.0544     .5578    4.6401
 -69        .0000     .0000    -.0706    1.1648    6.8290
 -70        .0000     .0000    -.0709    1.2417    6.9891
 -71        .0000     .0000    -.0561     .9315    5.4365
 -72        .0000     .0000    -.0561     .9315    5.4365
 -73      -3.7098     .0520    -.0561     .9314    5.4363
 -74      -2.3966     .0338    -.0587     .9725    5.6846
 -75      -2.3876     .0337    -.0587     .9726    5.6853
 -76      -2.8470     .0400    -.0621    1.0262    6.0090
 -77      -3.1981     .0449    -.0658    1.0844    6.3611
 -78      -3.2480     .0455    -.0618    1.0205    5.9745
 -79      -3.2524     .0455    -.0598     .9890    5.7844
 -80      -3.2721     .0458    -.0595     .9841    5.7546

                    Regression Constancy - CUSUM Test
                    ---------------------------------

  ********************************************************************
  I TIME  I   VALUE OF THE TEST STATISTIC     I   5% I  UPPER BOUND  I
  ********************************************************************
  I -69   I                  1.126            I   0  I     3.597     I
  I -70   I                  1.939            I   0  I     4.197     I
  I -71   I                  1.013            I   0  I     4.797     I
  I -74   I                  -.175            I   0  I     5.396     I
  I -75   I                  -.192            I   0  I     5.996     I
  I -76   I                   .464            I   0  I     6.595     I
  I -77   I                  1.008            I   0  I     7.195     I
  I -78   I                  2.917            I   0  I     7.794     I
  I -79   I                  4.029            I   0  I     8.394     I
  I -80   I                  4.470            I   0  I     8.994     I
  ********************************************************************
```

Table 50

```
---> **lm 3


************************************************************************

          LM-Test for simple Autocorrelation
          ---------------------------------

          Model: u=rho*u[j]+eps
             H0: rho.EQ.0
             H1: rho.NE.0

          Lag(j)     Value of Test-Statistic

            1                      .646
            2                     1.266
            3                      .172

          Under H0: N(0,1)

************************************************************************
```

Table 51

```
---> **normal

****************************************************************************

            Jarque-Bera Test for Normality of Residuals
            -------------------------------------------

            H0: Residuals are normally distributed
            H1: Residuals are not normally distributed

              Sum of residuals                        .000
              Sum of residuals**2                     .000
              Sum of residuals**3                     .000
              Sum of residuals**4                     .000

            Value of Jarque-Bera Statistic:      1.159
            Under H0: Chi-square(2)

****************************************************************************

---> **outlie

****************************************************************************

       Plot-Diagram of t-statistics of Outlier Coefficients
       ----------------------------------------------------

       =======================================================
        Period  I  t-value  I      * ... t-statistics        I
       -------------------------------------------------------
        1966    I      .396 I                  *             I
        1967    I      .322 I                 *              I
        1968    I    -1.469 I *                              I
        1969    I      .233 I                *               I
        1970    I     1.290 I                           *    I
        1971    I     -.918 I       *                        I
        1972    I      .901 I                        *       I
        1973    I     1.740 I                              * I
        1974    I     -.968 I      *                         I
        1975    I    -1.436 I *                              I
        1976    I     -.959 I      *                         I
        1977    I    -1.065 I     *                          I
        1978    I      .795 I                       *        I
        1979    I      .758 I                      *         I
        1980    I      .423 I                   *            I
       =======================================================

             MAX ABS(t-value) at 1973        1.740
             Significance Points:   see IAS-Manual

****************************************************************************
```

Table 52

References

ALDRICH, J. (1978): "An Alternative Derivation of Durbin's h Statistic", Econometrica 46, 1493-1494.

BELSEY, D.A. (1974): "Estimators of System of Simultaneous Equations and Computational Specification of Gremlin", Annals of Economic and Social Measurement 3/4, 551-614.

BREUSCH, T.S. (1978): "Testing for Autocorrelation in Dynamic Linear Models", Australian Economic Papers 17, 334-355.

BREUSCH, T.S. and Pagan, A.R. (1979): "A Simple Test for Heteroscedasticity and Random Coefficient Variation", Econometrica 47, 1287-1294.

BREUSCH, T.S. and Pagan A.R. (1980): The Lagrange Multiplier Test and its Applications to Model Specification in Econometrics", Review of Economic Studies 47, 239-253.

BROWN, R.L., Durbin, J. and Evans, J.M. (1975): "Techniques for Testing the Constancy of Regression Relationships over Time", JRSS B37, 149-192.

CHOW, G.G. (1960):"Tests for Equality between Sets of Coefficients in Two Linear Regressions", Econometrica 28, 591-605.

COOK, D. and Weisberg, S. (1982): Residuals and Influence in Regression, New York (Chapman and Hall).

DHRYMES, Ph. (1978): Introductory Econometrics, New York (Springer)

DURBIN, J. (1969): "Test for Serial Correlation in Regression Based on the Periodogram of Least Squares Residuals", Biometrika 56, 1-15.

DURBIN, J. (1970): "Testing for Serial Correlation in Least Squares Regression when Some of the Regressors are Lagged Dependent Variables", Econometrica 38, 410 -

ENGLE, R.F. (1982): "Wald, Likelihood Ratio, and Lagrange Multiplier Tests in Econometrics", to appear in Griliches and Intriligator (eds.): Handbook of Econometrics.

EPPS, T.W. and Epps, M.L. (1977): "The Robustness of Some Standard Tests for Autocorrelation and Heteroscedasticity when Both Problems are Present", Econometrica 45, 745-753

FAREBROTHER, R.W. (1979): "A Grouping Test for Misspecification", Econometrica 47, 209-210

FAREBROTHER, R.W. (1980): "The Durbin-Watson Test for Serial Correlation when there is no Intercept in the Regression", Econometrica 48, 1553-1563.

GASTWIRTH, J.L. and Owens, M.E.B. (1977): "On Classical Tests of Normality", Biometrika 64, 135-139.

GILES, D.E.A. and King, M. (1978): "Fourth Order Autocorrelation: Further Significance Points for the Wallis Test", Journal of Econometrics 8, 255-260.

GODFREY, L. (1978a): "Testing Against General Autoregressive and Moving Average Error Models when the Regressors include Lagged Dependent Variables", Econometrica 46, 1293-1302.

GODFREY, L. (1978b): "Testing for Higher Order Serial Correlation in Regression Equations when the Regressors include Lagged Endogenous Variables", Econometrica 46, 1303-1310

GODFREY, L. (1978c): "Testing for Multiplicative Heteroscedasticity", Journal of Econometrics 8, 227-236.

GODFREY, L., and Tremayne, A.R. (1978): "Testing for Fourth Order Autocorrelation in Dynamic Quarterly Regression Equations: Asymptotic Tests and Monte Carlo Evidence", unpublished manuscript, University of York.

GODFREY, L.,and Wickens, M.R. (1981): "Testing Linear and Log-Linear Regressions for Functional Form", Review of Economic Studies 48, 487-496.

GOLDFELD, S.M. and Quandt, R.E. (1965): "Some Tests for Homoskedasticity", JASA 60, 539-547.

HARVEY, A. (1976): "Estimating Regression Models with Multiplicative Heteroskedasticity", Econometrica 44, 461-465.

HARVEY, A., and Collier, P. (1977): "Testing for Functional Misspecification in Regression Analysis", Journal of Econometrics 6, 103-119.

HARVEY, A., and Phillips, G.D.A. (1980): "Testing for Serial Correlation in Simultaneous Equation Models", Econometrica 48, 747-759.

HAUSMAN, J.A. (1978): "Specification Tests in Econometrics", Econometrica 46, 1251-1271.

HAUSMAN, J.A., and Taylor, W.E. (1980): "Comparing Specification Tests and Classical Tests", Mimeo.

HAVLIK, P. and Sonnberger, H. (1983): "Implementation of the IAS-SYSTEM Test Processor", to appear.

HOLLY, A. (1982): "A Remark on Hausman's Specification Test", Econometrica 50, 749-759.

IMHOF, J.P. (1961): "Computing the Distribution of Quadratic Forms in Normal Variables", Biometrika 48, 419-426.

.JARQUE, C.M.,and Bero, A.K. (1980): "Efficient Tests for Normality, Homoskedasticity and Serial Independence of Regression Residuals", Economics Letters 6, 255-259.

JUDGE, G.E., Griffiths, W.E., Hill, R.C. and Lee, T.S. (1980): The Theory and Practice of Econometrics, New York (John Wiley).

KENDALL, M.G., and Stuart, A. (1969): The Advanced Theory of Statistics, Vol. I, 3rd. ed., London (Griffin).

KING, M.L. (1981): "The Durbin-Watson Test for Serial Correlation: Bounds for Regressions with Trend and/or Seasonal Dummy Variables", Econometrica 49, 1571-1582.

KING, M.L. (1983):"Testing for Autocorrelation in Linear Regression Models: A Survey", in King, M.L. and Giles, D.E.A. (eds.): Specification Analysis in the Linear Model: Essays in Honour of Donald Cochrane, to appear.

KRAMER, G. (1971): "On the Durbin-Watson Bounds Test in the Case of Regression Through the Origin", Jahrbücher für Nationalökonomie and Statistik 185, 345-358.

KRÄMER, W., Havlik, P., Maurer, J. and Sonnberger, H. (1983): "Diagnostic checking in practice", unpublished manuscript.

LOCKE, C. and Spurrier, J.D. (1977): "The Use of U-Statistics for Testing Normality Against Alternatives with Both Tails Heavy or Both Tails Light", Biometrika 64, 638-640.

MAURER, J. (1983): "The CUSUM and CUSUM of Squares Test with Dummy Variables", to appear.

MAURER, J., Sonnberger, H., Havlik, P. and Krämer, W. (1983): "The IAS-SYSTEM Level 3.3, User Reference Manual, Part Three: Testing", to appear

MAURER, J. and Pichelmann, K. (1983): "Gesamtwirtschaftliche Auswirkungen einer Arbeitszeitverkürzung - eine Simulationsstudie", unpublished Research Memorandum of the Institute for Advanced Studies.

McCABE, B. and Harrison, M.J. (1980): "Testing the Constancy of Regression Relationships over Time Using Least Squares Residuals", JRSS C. 29, 142-148.

MUNDUCH, G. (1983): "Aggregierte Analyse des Bausektors bezüglich Output-, Beschäftigungs- und Kapitalnachfrage", unpublished Research Memorandum of the Institute for Advanced Studies.

NERLOVE, M. and Wallis, K.F. (1966): "Use of the Durbin-Watson Statistic in Inappropriate Situations", Econometrica 34, 235-238.

NICHOLLS, D.F. and Pagan, A.R. (1983): " Heteroskedasticity in Models with Lagged Dependent Variables", to appear in Econometrica.

PAGAN, A.R. (1982): "Commentary on Model Selection", Paper given at the Meeting of Australasian Econometricians, Melbourne.

PAN JEI-JIAN (1968):"Distribution of the Noncircular Serial Correlation Coefficients", Selected Translations in Mathematical Statistics 7, Institute of Mathematical Statistics and the American Mathematical Society.

PEARSON, E.S., D'Agostino, R.B.D., and Bowman, K.O. (1977): "Tests for Departure from Normality: Comparison of Powers", Biometrika 64, 231-246.

PLOSSER, Ch. I., Schwert, G.W. and White, H. (1982): "Differencing as a Test of Specification", International Economic Review, 23, 535-552.

PYKE, R. (1959): "The Supremum and the Infimum of the Poisson Process", Annals of Mathematical Statistics 30, 569-576.

QUANDT, R.E. (1958):"The Estimation of the Parameters of a Linear Regression Obeying two Separate Regimes", JASA 53, 873-880.

QUANDT, R.E. (1960): "Tests of the Hypothesis that a Linear Regression System Obeys two Separate Regimes", JASA 55, 324-330.

RAMSEY, J.B. (1969): "Tests for Specification Error in Classical Linear Least Squares Regression Analysis", JRSS, B31, 350-371.

SAVIN, N.E., and White K.J. (1977): "The Durbin-Watson Test for Serial Correlation with Extreme Sample Sizes or Many Regressors", Econometrica 45, 1989-1996.

SCHMIDT, P. (1972): "A Generalization of the Durbin-Watson Test", Australian Economic Papers 11, 203-209.

SPIEGELHALTER, D.J. (1977): "A Test for Normality Against Symmetric Alternatives", Biometrika 64, 415-209.

THURSBY, J.G. (1979): "Alternative Specification Error Tests: A Comparative Study", JASA 74, 222-225.

THURSBY, J.G. (1981): "A Test Strategy for Discriminating between Autocorrelation and Misspecification in Regression Analysis", The Review of Economics and Statistics, 63, 117-123.

THURSBY, J.G. (1983): "Misspecification, Heteroscedasticity, and the Chow and Goldfeld-Quandt Tests", to appear in The Review of Economics and Statistics.

THURSBY, J.G., and Schmidt, P. (1977): "Some Properties of Tests for Specification Error in a Linear Regression Model", JASA 72, 635-641.

UTTS, Jessica M. (1982): "The Rainbow Test for Lack of Fit in Regression", Communications in Statistics-Theory and Methods 11, 1801-2815.

WALLIS, K.F. (1972): "Testing for Fourth-Order Autocorrelation in Quarterly Regression Equations", Econometrica 40, 617-636.

WEISBERG, S. (1980): Applied Linear Regression, New York (Wiley).

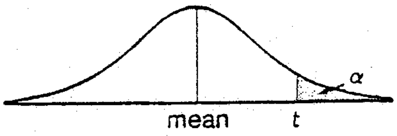
WHITE, H. (1980): "A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity", Econometrica 48, 817-838.

WHITE, H., and Mac Donald, G. (1980): "Some Large-Sample Tests for Non-Normality in the Linear Regression Model", JASA 75, 16-28.

APPENDIX a

Statistical Tables

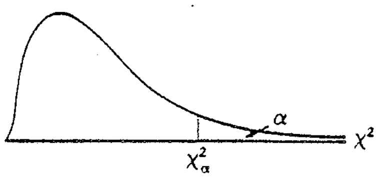
Table 1: The t-Distribution



	Right-tail area, α				
df	0.100	0.050	0.025	0.010	0.005
1	3.078	6.314	12.706	31.821	63.657
2	1.886	2.920	4.303	6.965	9.925
3	1.638	2.353	3.182	4.541	5.841
4	1.533	2.132	2.776	3.747	4.604
5	1.476	2.015	2.571	3.365	4.032
6	1.440	1.943	2.447	3.143	3.707
7	1.415	1.895	2.365	2.998	3.499
8	1.397	1.860	2.306	2.896	3.355
9	1.383	1.833	2.262	2.821	3.250
10	1.372	1.812	2.228	2.764	3.169
11	1.363	1.796	2.201	2.718	3.106
12	1.356	1.782	2.179	2.681	3.055
13	1.350	1.771	2.160	2.650	3.012
14	1.345	1.761	2.145	2.624	2.977
15	1.341	1.753	2.131	2.602	2.947
16	1.337	1.746	2.120	2.583	2.921
17	1.333	1.740	2.110	2.567	2.898
18	1.330	1.734	2.101	2.552	2.878
19	1.328	1.729	2.093	2.539	2.861
20	1.325	1.725	2.086	2.528	2.845
21	1.323	1.721	2.080	2.518	2.831
22	1.321	1.717	2.074	2.508	2.819
23	1.319	1.714	2.069	2.500	2.807
24	1.318	1.711	2.064	2.492	2.797
25	1.316	1.708	2.060	2.485	2.787
26	1.315	1.706	2.056	2.479	2.779
27	1.314	1.703	2.052	2.473	2.771
28	1.313	1.701	2.048	2.467	2.763
29	1.311	1.699	2.045	2.462	2.756
30	1.310	1.697	2.042	2.457	2.750
40	1.303	1.684	2.021	2.423	2.704
60	1.296	1.671	2.000	2.390	2.660
∞	1.282	1.645	1.960	2.326	2.576

Illustration: The *t* value for 12 degrees of freedom that bounds a right-tail area of 0.025 is 2.179.

Table 2: The Chi-Square Distribution



The following table provides the values of χ^2_α that correspond to a given right-tail area α and a specified number of degrees of freedom.

df	Right-tail area, α							
	0.99	0.975	0.95	0.90	0.10	0.05	0.025	0.01
1	0.00016	0.00098	0.0039	0.016	2.706	3.841	5.024	6.635
2	0.02001	0.05064	0.103	0.211	4.605	5.991	7.378	9.210
3	0.115	0.216	0.352	0.584	6.251	7.815	9.348	11.345
4	0.297	0.484	0.711	1.064	7.779	9.488	11.143	13.277
5	0.554	0.831	1.145	1.610	9.236	11.070	12.832	15.086
6	0.872	1.237	1.635	2.204	10.645	12.592	14.449	16.812
7	1.239	1.690	2.167	2.833	12.017	14.067	16.013	18.475
8	1.646	2.180	2.733	3.490	13.362	15.507	17.535	20.090
9	2.088	2.700	3.325	4.168	14.684	16.919	19.023	21.666
10	2.558	3.247	3.940	4.865	15.987	18.307	20.483	23.209
11	3.053	3.816	4.575	5.578	17.275	19.675	21.920	24.725
12	3.571	4.404	5.226	6.304	18.549	21.026	23.337	26.217
13	4.107	5.009	5.892	7.042	19.812	22.362	24.736	27.688
14	4.660	5.629	6.571	7.790	21.064	23.685	26.119	29.141
15	5.229	6.262	7.261	8.547	22.307	24.996	27.488	30.578
16	5.812	6.908	7.962	9.312	23.542	26.296	28.845	32.000
17	6.408	7.564	8.672	10.085	24.769	27.587	30.191	33.409
18	7.015	8.231	9.390	10.865	25.989	28.869	31.527	34.805
19	7.633	8.907	10.117	11.651	27.204	30.144	32.852	36.191
20	8.260	9.591	10.851	12.443	28.412	31.410	34.170	37.566
21	8.897	10.283	11.591	13.240	29.615	32.671	35.479	38.932
22	9.542	10.982	12.338	14.041	30.813	33.924	36.781	40.289
23	10.196	11.689	13.091	14.848	32.007	35.172	38.076	41.638
24	10.856	12.401	13.848	15.659	33.196	36.415	39.364	42.980
25	11.524	13.120	14.611	16.473	34.382	37.652	40.646	44.314
26	12.198	13.844	15.379	17.292	35.563	38.885	41.923	45.642
27	12.879	14.573	16.151	18.114	36.741	40.113	43.194	46.963
28	13.565	15.308	16.928	18.939	37.916	41.337	44.461	48.278
29	14.256	16.047	17.708	19.768	39.087	42.557	45.722	49.588
30	14.953	16.791	18.493	20.599	40.256	43.773	46.979	50.892

Table 3: The F Distribution (upper 5% points)

Degrees of freedom for numerator

Degrees of freedom for denominator

	1	2	3	4	5	6	7	8	9	10	12	15	20	24	30	40	60	120	∞
1	161	200	216	225	230	234	237	239	241	242	244	246	248	249	250	251	252	253	254
2	18.5	19.0	19.2	19.2	19.3	19.3	19.4	19.4	19.4	19.4	19.4	19.4	19.4	19.5	19.5	19.5	19.5	19.5	19.5
3	10.1	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81	8.79	8.74	8.70	8.66	8.64	8.62	8.59	8.57	8.55	8.53
4	7.71	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00	5.96	5.91	5.86	5.80	5.77	5.75	5.72	5.69	5.66	5.63
5	6.61	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.77	4.74	4.68	4.62	4.56	4.53	4.50	4.46	4.43	4.40	4.37
6	5.99	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10	4.06	4.00	3.94	3.87	3.84	3.81	3.77	3.74	3.70	3.67
7	5.59	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68	3.64	3.57	3.51	3.44	3.41	3.38	3.34	3.30	3.27	3.23
8	5.32	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39	3.35	3.28	3.22	3.15	3.12	3.08	3.04	3.01	2.97	2.93
9	5.12	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18	3.14	3.07	3.01	2.94	2.90	2.86	2.83	2.79	2.75	2.71
10	4.96	4.10	3.71	3.48	3.33	3.22	3.14	3.07	3.02	2.98	2.91	2.85	2.77	2.74	2.70	2.66	2.62	2.58	2.54
11	4.84	3.98	3.59	3.36	3.20	3.09	3.01	2.95	2.90	2.85	2.79	2.72	2.65	2.61	2.57	2.53	2.49	2.45	2.40
12	4.75	3.89	3.49	3.26	3.11	3.00	2.91	2.85	2.80	2.75	2.69	2.62	2.54	2.51	2.47	2.43	2.38	2.34	2.30
13	4.67	3.81	3.41	3.18	3.03	2.92	2.83	2.77	2.71	2.67	2.60	2.53	2.46	2.42	2.38	2.34	2.30	2.25	2.21
14	4.60	3.74	3.34	3.11	2.96	2.85	2.76	2.70	2.65	2.60	2.53	2.46	2.39	2.35	2.31	2.27	2.22	2.18	2.13
15	4.54	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.59	2.54	2.48	2.40	2.33	2.29	2.25	2.20	2.16	2.11	2.07
16	4.49	3.63	3.24	3.01	2.85	2.74	2.66	2.59	2.54	2.49	2.42	2.35	2.28	2.24	2.19	2.15	2.11	2.06	2.01
17	4.45	3.59	3.20	2.96	2.81	2.70	2.61	2.55	2.49	2.45	2.38	2.31	2.23	2.19	2.15	2.10	2.06	2.01	1.96
18	4.41	3.55	3.16	2.93	2.77	2.66	2.58	2.51	2.46	2.41	2.34	2.27	2.19	2.15	2.11	2.06	2.02	1.97	1.92
19	4.38	3.52	3.13	2.90	2.74	2.63	2.54	2.48	2.42	2.38	2.31	2.23	2.16	2.11	2.07	2.03	1.98	1.93	1.88
20	4.35	3.49	3.10	2.87	2.71	2.60	2.51	2.45	2.39	2.35	2.28	2.20	2.12	2.08	2.04	1.99	1.95	1.90	1.84
21	4.32	3.47	3.07	2.84	2.68	2.57	2.49	2.42	2.37	2.32	2.25	2.18	2.10	2.05	2.01	1.96	1.92	1.87	1.81
22	4.30	3.44	3.05	2.82	2.66	2.55	2.46	2.40	2.34	2.30	2.23	2.15	2.07	2.03	1.98	1.94	1.89	1.84	1.78
23	4.28	3.42	3.03	2.80	2.64	2.53	2.44	2.37	2.32	2.27	2.20	2.13	2.05	2.01	1.96	1.91	1.86	1.81	1.76
24	4.26	3.40	3.01	2.78	2.62	2.51	2.42	2.36	2.30	2.25	2.18	2.11	2.03	1.98	1.94	1.89	1.84	1.79	1.73
25	4.24	3.39	2.99	2.76	2.60	2.49	2.40	2.34	2.28	2.24	2.16	2.09	2.01	1.96	1.92	1.87	1.82	1.77	1.71
30	4.17	3.32	2.92	2.69	2.53	2.42	2.33	2.27	2.21	2.16	2.09	2.01	1.93	1.89	1.84	1.79	1.74	1.68	1.62
40	4.08	3.23	2.84	2.61	2.45	2.34	2.25	2.18	2.12	2.08	2.00	1.92	1.84	1.79	1.74	1.69	1.64	1.58	1.51
60	4.00	3.15	2.76	2.53	2.37	2.25	2.17	2.10	2.04	1.99	1.92	1.84	1.75	1.70	1.65	1.59	1.53	1.47	1.39
120	3.92	3.07	2.68	2.45	2.29	2.18	2.09	2.02	1.96	1.91	1.83	1.75	1.66	1.61	1.55	1.50	1.43	1.35	1.25
∞	3.84	3.00	2.60	2.37	2.21	2.10	2.01	1.94	1.88	1.83	1.75	1.67	1.57	1.52	1.46	1.39	1.32	1.22	1.00

Table 4: The Durbin-Watson Statistic d_L (5% significance points without any information on the X-matrix, from Farebrother, 1980)

T	K = 0	K = 1	K = 2	K = 3	K = 4	K = 5	K = 6	K = 7	K = 8	K = 9	K = 10	K = 11	K = 12	K = 13	K = 14	K = 15	K = 16	K = 17	K = 18	K = 19	K = 20	K = 21
2	0.012																					
3	0.168	0.006																				
4	0.355	0.105	0.004																			
5	0.478	0.248	0.070	0.002																		
6	0.584	0.358	0.180	0.050	0.002																	
7	0.677	0.462	0.275	0.136	0.037	0.001																
8	0.754	0.556	0.371	0.217	0.106	0.029	0.001															
9	0.820	0.635	0.460	0.303	0.175	0.085	0.023	0.001														
10	0.877	0.706	0.539	0.385	0.251	0.143	0.069	0.019	0.001													
11	0.927	0.768	0.610	0.460	0.326	0.211	0.120	0.058	0.016	0.001												
12	0.972	0.823	0.674	0.530	0.397	0.279	0.180	0.101	0.049	0.013	0.001											
13	1.012	0.872	0.731	0.593	0.464	0.345	0.241	0.154	0.087	0.042	0.011	0.001										
14	1.047	0.916	0.783	0.651	0.525	0.408	0.302	0.210	0.134	0.075	0.036	0.010	0.001									
15	1.079	0.955	0.829	0.704	0.583	0.467	0.361	0.266	9.185	0.118	0.066	0.031	0.008	0.001								
16	1.109	0.992	0.872	0.752	0.635	0.523	0.418	0.322	0.237	0.164	0.104	0.058	0.028	0.007	0.000							
17	1.136	1.024	0.911	0.797	0.684	0.575	0.472	0.376	0.288	0.211	0.146	0.093	0.052	0.025	0.007	0.000						
18	1.160	1.055	0.946	0.837	0.729	0.624	0.523	0.427	0.339	0.260	0.190	0.131	0.083	0.046	0.022	0.006	0.000					
19	1.183	1.082	0.979	0.875	0.771	0.669	0.570	0.476	0.388	0.307	0.235	0.171	0.118	0.075	0.041	0.020	0.005	0.000				
20	1.204	1.108	1.010	0.910	0.810	0.711	0.615	0.523	0.436	0.354	0.280	0.213	0.156	0.107	0.067	0.037	0.018	0.005	0.000			
21	1.224	1.132	1.038	0.942	0.846	0.751	0.657	0.567	0.481	0.400	0.324	0.256	0.195	0.142	0.097	0.061	0.034	0.016	0.004	0.000		
22	1.242	1.154	1.064	0.972	0.879	0.787	0.697	0.609	0.524	0.443	0.368	0.298	0.235	0.178	0.130	0.089	0.056	0.031	0.015	0.004	0.000	
23	1.259	1.175	1.088	1.000	0.911	0.822	0.734	0.648	0.565	0.485	0.410	0.339	0.274	0.216	0.164	0.119	0.081	0.051	0.028	0.014	0.004	0.000
24	1.275	1.194	1.111	1.026	0.940	0.854	0.769	0.685	0.604	0.525	0.450	0.380	0.314	0.254	0.199	0.151	0.110	0.075	0.047	0.026	0.012	0.003
25	1.290	1.212	1.132	1.050	0.967	0.884	0.802	0.720	0.641	0.563	0.489	0.419	0.353	0.291	0.235	0.184	0.140	0.101	0.069	0.044	0.024	0.011
26	1.304	1.229	1.152	1.073	0.993	0.913	0.833	0.753	0.676	0.600	0.527	0.457	0.390	0.328	0.271	0.218	0.171	0.130	0.094	0.064	0.040	0.022
27	1.318	1.245	1.171	1.094	1.017	0.940	0.862	0.785	0.709	0.635	•0.563	0.493	0.427	0.365	0.306	0.252	0.203	0.159	0.120	0.087	0.060	0.037
28	1.330	1.260	1.188	1.115	1.040	0.965	0.889	0.815	0.741	0.668	0.597	0.529	0.463	0.400	0.341	0.286	0.236	0.190	0.148	0.112	0.081	0.055
29	1.342	1.275	1.205	1.134	1.062	0.989	0.916	0.843	0.770	0.699	0.630	0.562	0.497	0.435	0.376	0.320	0.268	0.221	0.177	0.139	0.105	0.076
30	1.354	1.288	1.221	1.152	1.082	1.011	0.940	0.869	0.799	0.729	0.661	0.595	0.530	0.468	0.409	0.353	0.301	0.252	0.207	0.166	0.130	0.098
31	1.365	1.301	1.236	1.169	1.101	1.033	0.964	0.895	0.826	0.758	0.691	0.626	0.562	0.501	0.442	0.386	0.333	0.283	0.237	0.195	0.156	0.122
32	1.375	1.313	1.250	1.185	1.120	1.053	0.986	0.919	0.852	0.785	0.720	0.656	0.593	0.532	0.474	0.418	0.364	0.314	0.267	0.223	0.183	0.147
33	1.385	1.325	1.264	1.201	1.137	1.072	1.007	0.942	0.876	0.811	0.747	0.684	0.623	0.563	0.504	0.449	0.395	0.344	0.297	0.252	0.211	0.173
34	1.394	1.336	1.277	1.216	1.153	1.091	1.027	0.963	0.900	0.836	0.774	0.712	0.651	0.592	0.534	0.479	0.425	0.374	0.326	0.280	0.238	0.199
35	1.403	1.347	1.289	1.230	1.169	1.108	1.046	0.984	0.922	0.860	0.799	0.738	0.678	0.620	0.563	0.508	0.455	0.404	0.355	0.309	0.266	0.225
36	1.412	1.357	1.301	1.243	1.184	1.125	1.064	1.004	0.943	0.883	0.823	0.763	0.705	0.647	0.591	0.536	0.483	0.432	0.384	0.337	0.293	0.252
37	1.420	1.367	1.312	1.256	1.199	1.141	1.082	1.023	0.964	0.905	0.846	0.787	0.730	0.673	0.618	0.564	0.511	0.460	0.412	0.365	0.321	0.279
38	1.428	1.376	1.323	1.268	1.212	1.156	1.099	1.041	0.983	0.925	0.868	0.811	0.754	0.698	0.644	0.590	0.538	0.488	0.439	0.392	0.347	0.305
39	1.436	1.385	1.333	1.280	1.225	1.170	1.114	1.058	1.002	0.945	0.889	0.833	0.778	0.723	0.669	0.616	0.564	0.514	0.466	0.419	0.374	0.331
40	1.443	1.394	1.343	1.291	1.238	1.184	1.130	1.075	1.020	0.965	0.909	0.854	0.800	0.746	0.693	0.641	0.590	0.540	0.492	0.445	0.400	0.357
45	1.476	1.432	1.387	1.341	1.294	1.246	1.197	1.148	1.099	1.049	1.000	0.950	0.900	0.851	0.802	0.753	0.706	0.658	0.612	0.567	0.523	0.480
50	1.504	1.464	1.424	1.382	1.340	1.297	1.253	1.209	1.164	1.120	1.075	1.029	0.984	0.939	0.894	0.849	0.804	0.760	0.717	0.674	0.631	0.590
55	1.528	1.492	1.455	1.417	1.379	1.340	1.300	1.260	1.219	1.179	1.138	1.096	1.055	1.013	0.972	0.930	0.889	0.848	0.807	0.766	0.726	0.687
60	1.549	1.516	1.482	1.447	1.412	1.376	1.340	1.303	1.266	...29	1.191	1.153	1.115	1.077	1.038	1.000	0.962	0.923	0.885	0.847	0.810	0.772
65	1.568	1.537	1.505	1.474	1.441	1.408	1.375	1.341	1.307	1.272	1.238	1.202	1.167	1.132	1.096	1.061	1.025	0.989	0.953	0.918	0.882	0.847
70	1.584	1.555	1.526	1.497	1.467	1.436	1.405	1.374	1.342	1.310	1.278	1.245	1.213	1.180	1.147	1.113	1.080	1.047	1.013	0.980	0.947	0.914
75	1.599	1.572	1.545	1.517	1.489	1.461	1.432	1.403	1.373	1.344	1.313	1.283	1.253	1.222	1.191	1.160	1.129	1.098	1.066	1.035	1.004	0.972
80	1.612	1.587	1.561	1.536	1.509	1.483	1.456	1.429	1.401	1.373	1.345	1.317	1.288	1.259	1.230	1.201	1.172	1.143	1.113	1.084	1.054	1.025
85	1.624	1.600	1.576	1.552	1.527	1.502	1.477	1.452	1.426	1.400	1.373	1.347	1.320	1.293	1.266	1.238	1.211	1.183	1.155	1.128	1.100	1.072
90	1.635	1.613	1.590	1.567	1.544	1.520	1.497	1.472	1.448	1.423	1.399	1.373	1.348	1.323	1.297	1.271	1.245	1.219	1.193	1.617	1.141	1.114
95	1.645	1.624	1.603	1.581	1.559	1.537	1.514	1.491	1.468	1.445	1.422	1.398	1.374	1.350	1.326	1.301	1.277	1.252	1.227	1.202	1.177	1.152
100	1.654	1.634	1.614	1.593	1.573	1.551	1.530	1.508	1.487	1.465	1.442	1.420	1.397	1.374	1.352	1.328	1.305	1.282	1.258	1.235	1.211	1.187
150	1.720	1.706	1.693	1.679	1.666	1.652	1.638	1.624	1.609	1.595	1.580	1.566	1.551	1.536	1.521	1.506	1.491	1.476	1.461	1.445	1.430	1.414
200	1.759	1.748	1.738	1.728	1.718	1.708	1.697	1.687	1.676	1.666	1.655	1.644	1.633	1.622	1.611	1.600	1.589	1.578	1.567	1.556	1.544	1.533

Table 5: The Durbin-Watson Statistic for Regressions with an Intercept (5% significance points for d_L and d_U)

T	K = 2		K = 3		K = 4		K = 5		K = 6	
	d_L	d_U	d_L	d_U	d_L	d_U	d_L	d_U	d_L	d_U
15	1.08	1.36	0.95	1.54	0.82	1.75	0.69	1.97	0.56	2.21
16	1.10	1.37	0.98	1.54	0.86	1.73	0.74	1.93	0.62	2.15
17	1.13	1.38	1.02	1.54	0.90	1.71	0.78	1.90	0.67	2.10
18	1.16	1.39	1.05	1.53	0.93	1.69	0.82	1.87	0.71	2.06
19	1.18	1.40	1.08	1.53	0.97	1.68	0.86	1.85	0.75	2.02
20	1.20	1.41	1.10	1.54	1.00	1.68	0.90	1.83	0.79	1.99
21	1.22	1.42	1.13	1.54	1.03	1.67	0.93	1.81	0.83	1.96
22	1.24	1.43	1.15	1.54	1.05	1.66	0.96	1.80	0.86	1.94
23	1.26	1.44	1.17	1.54	1.08	1.66	0.99	1.79	0.90	1.92
24	1.27	1.45	1.19	1.55	1.10	1.66	1.01	1.78	0.93	1.90
25	1.29	1.45	1.21	1.55	1.12	1.66	1.04	1.77	0.95	1.89
26	1.30	1.46	1.22	1.55	1.14	1.65	1.06	1.76	0.98	1.88
27	1.32	1.47	1.24	1.56	1.16	1.65	1.08	1.76	1.01	1.86
28	1.33	1.48	1.26	1.56	1.18	1.65	1.10	1.75	1.03	1.85
29	1.34	1.48	1.27	1.56	1.20	1.65	1.12	1.74	1.05	1.84
30	1.35	1.49	1.28	1.57	1.21	1.65	1.14	1.74	1.07	1.83
31	1.36	1.50	1.30	1.57	1.23	1.65	1.16	1.74	1.09	1.83
32	1.37	1.50	1.31	1.57	1.24	1.65	1.18	1.73	1.11	1.82
33	1.38	1.51	1.32	1.58	1.26	1.65	1.19	1.73	1.13	1.81
34	1.39	1.51	1.33	1.58	1.27	1.65	1.21	1.73	1.15	1.81
35	1.40	1.52	1.34	1.58	1.28	1.65	1.22	1.73	1.16	1.80
36	1.41	1.52	1.35	1.59	1.29	1.65	1.24	1.73	1.18	1.80
37	1.42	1.53	1.36	1.59	1.31	1.66	1.25	1.72	1.19	1.80
38	1.43	1.54	1.37	1.59	1.32	1.66	1.26	1.72	1.21	1.79
39	1.43	1.54	1.38	1.60	1.33	1.66	1.27	1.72	1.22	1.79
40	1.44	1.54	1.39	1.60	1.34	1.66	1.29	1.72	1.23	1.79
45	1.48	1.57	1.43	1.62	1.38	1.67	1.34	1.72	1.29	1.78
50	1.50	1.59	1.46	1.63	1.42	1.67	1.38	1.72	1.34	1.77
55	1.53	1.60	1.49	1.64	1.45	1.68	1.41	1.72	1.38	1.77
60	1.55	1.62	1.51	1.65	1.48	1.69	1.44	1.73	1.41	1.77
65	1.57	1.63	1.54	1.66	1.50	1.70	1.47	1.73	1.44	1.77
70	1.58	1.64	1.55	1.67	1.52	1.70	1.49	1.74	1.46	1.77
75	1.60	1.65	1.57	1.68	1.54	1.71	1.51	1.74	1.49	1.77
80	1.61	1.66	1.59	1.69	1.56	1.72	1.53	1.74	1.51	1.77
85	1.62	1.67	1.60	1.70	1.57	1.72	1.55	1.75	1.52	1.77
90	1.63	1.68	1.61	1.70	1.59	1.73	1.57	1.75	1.54	1.78
95	1.64	1.69	1.62	1.71	1.60	1.73	1.58	1.75	1.56	1.78
100	1.65	1.69	1.63	1.72	1.61	1.74	1.59	1.76	1.57	1.78

Table 6: The Durbin-Watson Statistic for Regressions with a Full Set of Quarterly Seasonal Dummy Variables (5% significance points, from King, 1981)

	k = 4	k = 5		k = 6		k = 7		k = 8		k = 9		k = 10		k = 11	
T	$d_L = d_U$	d_L	d_U	d_L	d_U	d_L	d_U	d_L	d_U	d_L	d_U	d_L	d_U	d_L	d_U
15	.990	.838	1.156	.688	1.352	.545	1.600	.415	1.881	.302	2.284	.218	2.845	.148	3.139
16	1.025	.882	1.171	.739	1.361	.601	1.566	.473	1.837	.357	2.143	.259	2.653	.190	2.999
17	1.053	.919	1.193	.783	1.359	.652	1.555	.526	1.778	.411	2.042	.308	2.381	.232	2.880
18	1.086	.959	1.218	.830	1.371	.704	1.552	.582	1.753	.468	1.994	.363	2.274	.276	2.671
19	1.115	.995	1.239	.873	1.382	.752	1.549	.634	1.733	.522	1.947	.417	2.186	.323	2.498
20	1.140	1.027	1.255	.910	1.393	.795	1.541	.680	1.719	.571	1.905	.467	2.133	.372	2.382
21	1.161	1.053	1.271	.942	1.397	.832	1.539	.722	1.697	.616	1.873	.514	2.067	.419	2.290
22	1.185	1.082	1.289	.976	1.407	.870	1.541	.764	1.688	.661	1.852	.561	2.030	.467	2.233
23	1.206	1.108	1.305	1.007	1.417	.905	1.543	.804	1.680	.704	1.833	.606	1.996	.514	2.180
24	1.225	1.131	1.318	1.034	1.426	.937	1.543	.839	1.675	.742	1.814	.648	1.971	.556	2.135
25	1.241	1.151	1.331	1.059	1.432	.965	1.544	.871	1.666	.777	1.799	.685	1.941	.596	2.096
26	1.259	1.172	1.345	1.084	1.441	.994	1.547	.903	1.662	.813	1.788	.723	1.922	.636	2.068
27	1.275	1.192	1.358	1.107	1.449	1.020	1.551	.933	1.659	.846	1.778	.759	1.904	.674	2.041
28	1.290	1.210	1.369	1.128	1.458	1.045	1.552	.960	1.658	.876	1.769	.792	1.890	.709	2.016
29	1.303	1.226	1.379	1.147	1.463	1.066	1.555	.985	1.654	.903	1.760	.822	1.874	.741	1.995
30	1.316	1.242	1.390	1.166	1.471	1.089	1.559	1.010	1.653	.931	1.755	.852	1.862	.774	1.977
31	1.329	1.258	1.401	1.184	1.478	1.109	1.562	1.033	1.653	.957	1.750	.880	1.852	.804	1.961
32	1.341	1.272	1.410	1.201	1.485	1.129	1.565	1.055	1.653	.981	1.744	.906	1.844	.832	1.946
33	1.352	1.285	1.418	1.216	1.490	1.146	1.568	1.075	1.651	1.003	1.740	.931	1.834	.858	1.933
34	1.363	1.298	1.427	1.232	1.497	1.164	1.572	1.095	1.652	1.025	1.737	.955	1.827	.885	1.922
35	1.374	1.311	1.436	1.246	1.503	1.180	1.575	1.113	1.652	1.046	1.734	.978	1.820	.909	1.911
36	1.384	1.323	1.444	1.260	1.509	1.196	1.578	1.131	1.653	1.065	1.731	.999	1.815	.932	1.901
37	1.392	1.333	1.451	1.272	1.514	1.210	1.581	1.147	1.653	1.083	1.729	1.019	1.809	.954	1.892
38	1.402	1.344	1.459	1.285	1.520	1.225	1.585	1.163	1.654	1.101	1.727	1.038	1.804	.975	1.885
39	1.410	1.354	1.466	1.297	1.525	1.238	1.588	1.179	1.655	1.118	1.726	1.057	1.800	.996	1.878
40	1.419	1.364	1.472	1.308	1.530	1.251	1.591	1.193	1.657	1.134	1.725	1.075	1.797	1.015	1.871
45	1.455	1.407	1.503	1.358	1.553	1.308	1.606	1.256	1.662	1.205	1.721	1.152	1.782	1.099	1.846
50	1.486	1.443	1.529	1.399	1.574	1.354	1.621	1.309	1.670	1.262	1.721	1.215	1.774	1.168	1.830
55	1.513	1.474	1.551	1.434	1.591	1.394	1.633	1.352	1.677	1.311	1.723	1.268	1.770	1.225	1.819
60	1.536	1.500	1.570	1.464	1.607	1.427	1.645	1.389	1.685	1.351	1.726	1.313	1.768	1.274	1.812
65	1.555	1.523	1.588	1.489	1.621	1.456	1.656	1.421	1.692	1.386	1.729	1.351	1.767	1.315	1.807
70	1.573	1.543	1.603	1.512	1.634	1.481	1.666	1.449	1.699	1.417	1.733	1.384	1.768	1.351	1.804
75	1.589	1.561	1.616	1.532	1.645	1.503	1.675	1.473	1.705	1.444	1.737	1.413	1.769	1.383	1.802
80	1.603	1.577	1.629	1.550	1.656	1.523	1.683	1.495	1.712	1.467	1.741	1.439	1.771	1.410	1.801
85	1.616	1.591	1.640	1.566	1.665	1.540	1.691	1.515	1.717	1.489	1.745	1.462	1.772	1.435	1.801
90	1.627	1.604	1.650	1.580	1.674	1.557	1.698	1.532	1.723	1.508	1.748	1.483	1.775	1.458	1.801
95	1.638	1.616	1.660	1.594	1.682	1.571	1.705	1.548	1.728	1.525	1.752	1.502	1.777	1.478	1.802
100	1.648	1.627	1.668	1.606	1.690	1.584	1.711	1.563	1.733	1.541	1.756	1.519	1.779	1.496	1.803

Table 7: The Durbin-Watson Statistic for Regressions with an Intercept and a Linear Trend (5% significance points, from King, 1981)

	$k = 2$	$k = 3$		$k = 4$		$k = 5$		$k = 6$		$k = 7$		$k = 8$		$k = 9$	
T	$d_L = d_U$	d_L	d_U	d_L	d_U	d_L	d_U	d_L	d_U	d_L	d_U	d_L	d_U	d_L	d_U
15	1.360	1.228	1.542	1.093	1.750	.956	1.977	.821	2.220	.692	2.471	.569	2.727	.457	2.979
16	1.370	1.247	1.538	1.119	1.727	.990	1.935	.862	2.157	.737	2.388	.618	2.624	.507	2.860
17	1.381	1.264	1.535	1.143	1.710	1.021	1.900	.899	2.104	.779	2.317	.664	2.537	.555	2.757
18	1.391	1.280	1.535	1.166	1.696	1.050	1.872	.934	2.060	.819	2.257	.707	2.461	.600	2.667
19	1.401	1.296	1.535	1.188	1.685	1.077	1.848	.966	2.023	.856	2.206	.748	2.396	.644	2.589
20	1.410	1.311	1.536	1.207	1.676	1.102	1.828	.996	1.991	.890	2.162	.786	2.339	.685	2.521
21	1.420	1.325	1.538	1.226	1.669	1.126	1.811	1.024	1.963	.922	2.123	.822	2.290	.724	2.460
22	1.429	1.338	1.540	1.244	1.664	1.148	1.797	1.050	1.940	.953	2.090	.856	2.246	.761	2.407
23	1.437	1.350	1.543	1.260	1.660	1.168	1.785	1.075	1.920	.981	2.061	.887	2.208	.795	2.360
24	1.446	1.362	1.546	1.276	1.656	1.187	1.775	1.098	1.902	1.007	2.035	.917	2.174	.828	2.318
25	1.454	1.373	1.549	1.291	1.654	1.206	1.766	1.119	1.886	1.032	2.012	.945	2.144	.859	2.280
26	1.461	1.384	1.553	1.304	1.652	1.223	1.759	1.140	1.873	1.056	1.992	.972	2.117	.888	2.246
27	1.469	1.394	1.556	1.318	1.651	1.239	1.753	1.159	1.861	1.078	1.974	.996	2.093	.915	2.216
28	1.476	1.404	1.559	1.330	1.650	1.254	1.747	1.177	1.850	1.099	1.958	1.020	2.071	.941	2.188
29	1.483	1.413	1.563	1.342	1.650	1.269	1.743	1.194	1.841	1.118	1.944	1.042	2.052	.966	2.164
30	1.489	1.422	1.566	1.353	1.650	1.282	1.739	1.210	1.833	1.137	1.931	1.063	2.034	.989	2.141
31	1.496	1.431	1.570	1.364	1.650	1.296	1.735	1.226	1.825	1.155	1.920	1.083	2.018	1.011	2.120
32	1.502	1.439	1.573	1.374	1.650	1.308	1.732	1.240	1.819	1.172	1.909	1.102	2.004	1.032	2.102
33	1.508	1.447	1.577	1.384	1.651	1.320	1.730	1.254	1.813	1.187	1.900	1.120	1.991	1.052	2.085
34	1.514	1.454	1.580	1.394	1.652	1.331	1.728	1.267	1.808	1.203	1.891	1.137	1.978	1.071	2.069
35	1.519	1.462	1.584	1.403	1.653	1.342	1.726	1.280	1.803	1.217	1.883	1.154	1.967	1.090	2.054
36	1.524	1.469	1.587	1.411	1.654	1.352	1.724	1.292	1.799	1.231	1.876	1.169	1.957	1.107	2.041
37	1.530	1.475	1.590	1.419	1.655	1.362	1.723	1.304	1.795	1.244	1.870	1.184	1.948	1.123	2.029
38	1.535	1.482	1.594	1.427	1.656	1.372	1.722	1.315	1.792	1.257	1.864	1.198	1.939	1.139	2.017
39	1.540	1.488	1.597	1.435	1.658	1.381	1.721	1.325	1.789	1.269	1.859	1.212	1.932	1.154	2.007
40	1.544	1.494	1.600	1.442	1.659	1.389	1.721	1.335	1.786	1.281	1.854	1.225	1.924	1.169	1.997
45	1.566	1.521	1.615	1.475	1.666	1.429	1.720	1.381	1.776	1.332	1.835	1.283	1.895	1.233	1.958
50	1.585	1.545	1.628	1.503	1.674	1.461	1.721	1.418	1.771	1.375	1.822	1.330	1.875	1.286	1.930
55	1.601	1.565	1.641	1.527	1.681	1.489	1.724	1.450	1.768	1.411	1.814	1.371	1.861	1.330	1.909
60	1.616	1.583	1.652	1.548	1.689	1.513	1.727	1.478	1.767	1.442	1.808	1.405	1.850	1.368	1.894
65	1.629	1.598	1.662	1.567	1.696	1.535	1.731	1.502	1.767	1.469	1.805	1.435	1.843	1.401	1.882
70	1.641	1.613	1.672	1.583	1.703	1.553	1.735	1.523	1.768	1.492	1.802	1.461	1.838	1.430	1.874
75	1.652	1.625	1.680	1.598	1.709	1.570	1.739	1.542	1.770	1.513	1.801	1.484	1.834	1.455	1.867
80	1.662	1.637	1.688	1.611	1.715	1.585	1.743	1.559	1.772	1.532	1.801	1.505	1.831	1.478	1.861
85	1.671	1.647	1.696	1.623	1.721	1.599	1.747	1.574	1.774	1.549	1.801	1.524	1.829	1.498	1.857
90	1.679	1.657	1.703	1.634	1.726	1.611	1.751	1.588	1.776	1.564	1.801	1.540	1.827	1.516	1.854
95	1.687	1.666	1.709	1.645	1.732	1.623	1.755	1.601	1.778	1.578	1.802	1.556	1.827	1.533	1.852
100	1.694	1.674	1.715	1.654	1.736	1.633	1.758	1.612	1.780	1.591	1.803	1.570	1.826	1.548	1.850

Table 8: The Durbin-Watson Statistic for Regressions with a Full Set of Seasonal Dummy Variables and a Linear Trend (5% significance points, from King, 1981)

	$k = 5$	$k = 6$		$k = 7$		$k = 8$		$k = 9$		$k = 10$		$k = 11$		$k = 12$	
T	$d_L = d_U$	d_L	d_U	d_L	d_U	d_L	d_U	d_L	d_U	d_L	d_U	d_L	d_U	d_L	d_U
15	1.153	.993	1.348	.833	1.598	.680	1.879	.537	2.283	.419	2.844	.331	3.138	.268	3.367
16	1.164	1.013	1.352	.861	1.562	.713	1.832	.574	2.140	.448	2.646	.339	2.999	.253	3.230
17	1.190	1.050	1.356	.908	1.553	.769	1.776	.635	2.041	.511	2.380	.400	2.880	.319	3.094
18	1.216	1.084	1.369	.950	1.551	.817	1.752	.687	1.994	.566	2.273	.453	2.671	.358	2.999
19	1.238	1.114	1.380	.987	1.548	.861	1.732	.736	1.947	.617	2.185	.506	2.498	.405	2.875
20	1.251	1.133	1.388	1.012	1.539	.891	1.716	.771	1.903	.655	2.131	.544	2.381	.442	2.734
21	1.270	1.158	1.395	1.044	1.538	.929	1.696	.815	1.873	.703	2.067	.596	2.289	.495	2.559
22	1.288	1.182	1.406	1.074	1.541	.964	1.687	.854	1.852	.746	2.029	.641	2.233	.542	2.459
23	1.305	1.204	1.416	1.100	1.543	.996	1.680	.890	1.833	.786	1.996	.685	2.180	.587	2.380
24	1.316	1.220	1.424	1.121	1.541	1.020	1.673	.919	1.813	.818	1.970	.719	2.134	.624	2.325
25	1.330	1.239	1.431	1.144	1.543	1.048	1.665	.951	1.798	.854	1.941	.759	2.096	.666	2.264
26	1.344	1.257	1.440	1.166	1.547	1.074	1.662	.980	1.788	.887	1.922	.795	2.068	.704	2.222
27	1.357	1.273	1.449	1.186	1.550	1.098	1.659	1.008	1.778	.918	1.904	.829	2.041	.741	2.185
28	1.367	1.286	1.456	1.202	1.552	1.117	1.657	1.031	1.768	.944	1.890	.857	2.016	.771	2.154
29	1.379	1.301	1.463	1.220	1.555	1.138	1.653	1.055	1.760	.971	1.873	.887	1.994	.804	2.122
30	1.390	1.315	1.470	1.237	1.559	1.158	1.653	1.078	1.755	.997	1.862	.916	1.977	.835	2.098
31	1.400	1.328	1.478	1.253	1.562	1.177	1.652	1.099	1.750	1.021	1.852	.942	1.961	.864	2.075
32	1.409	1.338	1.484	1.266	1.564	1.193	1.652	1.118	1.744	1.042	1.843	.966	1.946	.889	2.056
33	1.418	1.350	1.490	1.280	1.568	1.209	1.651	1.137	1.740	1.063	1.833	.989	1.933	.916	2.036
34	1.427	1.361	1.496	1.294	1.572	1.225	1.651	1.155	1.737	1.084	1.826	1.012	1.922	.940	2.021
35	1.436	1.372	1.503	1.307	1.575	1.240	1.652	1.172	1.734	1.103	1.820	1.034	1.911	.964	2.006
36	1.443	1.381	1.508	1.318	1.578	1.253	1.653	1.187	1.731	1.120	1.815	1.053	1.901	.985	1.993
37	1.451	1.391	1.514	1.329	1.581	1.267	1.653	1.202	1.729	1.138	1.808	1.072	1.892	1.006	1.980
38	1.458	1.400	1.519	1.340	1.585	1.279	1.654	1.217	1.727	1.154	1.804	1.090	1.885	1.026	1.969
39	1.466	1.409	1.525	1.351	1.588	1.292	1.655	1.231	1.726	1.170	1.800	1.108	1.878	1.045	1.959
40	1.472	1.417	1.530	1.360	1.591	1.303	1.656	1.244	1.724	1.184	1.796	1.124	1.871	1.063	1.950
45	1.503	1.454	1.553	1.405	1.606	1.354	1.662	1.302	1.721	1.250	1.782	1.196	1.846	1.143	1.912
50	1.529	1.485	1.573	1.441	1.620	1.396	1.670	1.350	1.721	1.303	1.774	1.256	1.830	1.208	1.887
55	1.551	1.512	1.591	1.472	1.633	1.431	1.677	1.390	1.723	1.348	1.770	1.305	1.819	1.262	1.870
60	1.570	1.535	1.607	1.498	1.645	1.461	1.685	1.423	1.726	1.385	1.768	1.346	1.812	1.307	1.857
65	1.587	1.555	1.621	1.521	1.656	1.487	1.692	1.453	1.729	1.418	1.767	1.382	1.807	1.346	1.848
70	1.603	1.572	1.634	1.542	1.666	1.510	1.699	1.478	1.733	1.446	1.768	1.413	1.804	1.380	1.841
75	1.616	1.588	1.645	1.560	1.675	1.530	1.705	1.501	1.737	1.471	1.769	1.440	1.802	1.409	1.836
80	1.629	1.602	1.656	1.576	1.683	1.548	1.711	1.521	1.741	1.493	1.771	1.464	1.801	1.436	1.833
85	1.640	1.615	1.665	1.590	1.691	1.565	1.717	1.539	1.745	1.513	1.772	1.486	1.801	1.459	1.830
90	1.650	1.627	1.674	1.603	1.698	1.579	1.723	1.555	1.748	1.530	1.775	1.505	1.801	1.480	1.828
95	1.660	1.638	1.682	1.615	1.705	1.593	1.728	1.570	1.752	1.546	1.777	1.523	1.802	1.499	1.827
100	1.668	1.648	1.690	1.626	1.711	1.605	1.733	1.583	1.756	1.561	1.779	1.539	1.803	1.516	1.827

Table 9: The Wallis d_4 Statistic for Regressions with an Intercept and Quarterly Dummy Variables (5% significance points, from Wallis, 1972)

	K = 5		K = 6		K = 7		K = 8		K = 9	
T	$d_{4,L}$	$d_{4,U}$	$d_{4,L}$	$d_{4,U}$	$d_{4,L}$	$d_{4,U}$	$d_{4,L}$	$d_{4,U}$	$d_{4,L}$	$d_{4,U}$
16	1.156	1.381	1.031	1.532	0.902	1.776	0.777	2.191	0.693	2.238
20	1.228	1.428	1.123	1.556	1.013	1.726	0.899	1.954	0.806	2.042
24	1.287	1.459	1.199	1.565	1.107	1.694	1.011	1.856	0.928	1.949
28	1.337	1.487	1.261	1.576	1.181	1.679	1.099	1.803	1.025	1.889
32	1.379	1.511	1.312	1.587	1.243	1.673	1.171	1.773	1.104	1.850
36	1.414	1.532	1.355	1.598	1.293	1.672	1.230	1.755	1.170	1.824
40	1.445	1.550	1.391	1.609	1.336	1.674	1.279	1.745	1.225	1.807
44	1.471	1.567	1.422	1.620	1.373	1.677	1.321	1.739	1.272	1.795
48	1.494	1.582	1.450	1.630	1.404	1.681	1.357	1.737	1.312	1.788
52	1.514	1.595	1.474	1.639	1.432	1.686	1.389	1.736	1.347	1.782
56	1.533	1.608	1.495	1.648	1.456	1.691	1.416	1.736	1.377	1.779
60	1.549	1.619	1.514	1.656	1.478	1.696	1.441	1.737	1.404	1.777
64	1.564	1.629	1.531	1.664	1.497	1.700	1.463	1.739	1.429	1.776
68	1.577	1.639	1.546	1.671	1.515	1.705	1.482	1.741	1.450	1.775
72	1.590	1.648	1.560	1.678	1.531	1.710	1.500	1.743	1.470	1.776
76	1.601	1.656	1.573	1.685	1.545	1.714	1.517	1.746	1.488	1.776
80	1.611	1.663	1.585	1.691	1.559	1.719	1.531	1.748	1.504	1.777
84	1.621	1.671	1.596	1.696	1.571	1.723	1.545	1.751	1.519	1.778
88	1.630	1.677	1.607	1.702	1.582	1.727	1.558	1.753	1.533	1.779
92	1.639	1.684	1.616	1.707	1.593	1.731	1.570	1.756	1.546	1.781
96	1.647	1.690	1.625	1.712	1.603	1.735	1.580	1.759	1.558	1.782
100	1.654	1.695	1.633	1.717	1.612	1.739	1.591	1.761	1.569	1.784

Table 10: The Wallis d_4 Statistic for Regressions with an Intercept (5% significance points, from Wallis, 1972)

	K = 2		K = 3		K = 4		K = 5		K = 6	
T	$d_{4,L}$	$d_{4,U}$	$d_{4,L}$	$d_{4,U}$	$d_{4,L}$	$d_{4,U}$	$d_{4,L}$	$d_{4,U}$	$d_{4,L}$	$d_{4,U}$
16	0.774	0.982	0.662	1.109	0.549	1.275	0.435	1.381	0.350	1.532
20	0.924	1.102	0.827	1.203	0.728	1.327	0.626	1.428	0.544	1.556
24	1.036	1.189	0.953	1.273	0.867	1.371	0.779	1.459	0.702	1.565
28	1.123	1.257	1.050	1.328	0.975	1.410	0.898	1.487	0.828	1.576
32	1.192	1.311	1.127	1.373	1.061	1.443	0.993	1.511	0.929	1.587
36	1.248	1.355	1.191	1.410	1.131	1.471	1.070	1.532	1.013	1.598
40	1.295	1.392	1.243	1.442	1.190	1.496	1.135	1.550	1.082	1.609
44	1.335	1.423	1.288	1.469	1.239	1.518	1.189	1.567	1.141	1.620
48	1.369	1.451	1.326	1.493	1.281	1.537	1.236	1.582	1.191	1.630
52	1.399	1.475	1.359	1.513	1.318	1.554	1.276	1.595	1.235	1.639
56	1.426	1.496	1.389	1.532	1.351	1.569	1.312	1.608	1.273	1.648
60	1.449	1.515	1.415	1.548	1.379	1.583	1.343	1.619	1.307	1.656
64	1.470	1.532	1.438	1.563	1.405	1.596	1.371	1.629	1.337	1.664
68	1.489	1.548	1.459	1.577	1.427	1.608	1.396	1.639	1.364	1.671
72	1.507	1.562	1.478	1.589	1.448	1.618	1.418	1.648	1.388	1.678
76	1.522	1.574	1.495	1.601	1.467	1.628	1.439	1.656	1.411	1.685
80	1.537	1.586	1.511	1.611	1.484	1.637	1.457	1.663	1.431	1.691
84	1.550	1.597	1.525	1.621	1.500	1.646	1.475	1.671	1.449	1.696
88	1.562	1.607	1.539	1.630	1.515	1.654	1.490	1.677	1.466	1.702
92	1.574	1.617	1.551	1.639	1.528	1.661	1.505	1.684	1.482	1.707
96	1.584	1.626	1.563	1.647	1.541	1.668	1.519	1.690	1.496	1.712
100	1.594	1.634	1.573	1.654	1.552	1.674	1.531	1.695	1.510	1.717

Table 11: Significance Values for the CUSUM of Squares Statistic
(Computed from Durbin, 1969; n=1/2(T-K) -1; 5% significance level)

C(1)	.475
C(1.5)	.492
C(2)	.509
C(2.5)	.488
C(3)	.467
C(3.5)	.457
C(4)	.446
C(4.5)	.434
C(5)	.422
C(5.5)	.411
C(6)	.400
C(6.5)	.392
C(7)	.383
C(7.5)	.375
C(8)	.367
C(8.5)	.360
C(9)	.353
C(9.5)	.346
C(10)	.340
C(10.5)	.335
C(11)	.329
C(11.5)	.324
C(12)	.319
C(12.5)	.314
C(13)	.309
C(13.5)	.305
C(14)	.301
C(14.5)	.297
C(15)	.293
C(15.5)	.289
C(16)	.286
C(16.5)	.282
C(17)	.279
C(17.5)	.276
C(18)	.273
C(18.5)	.270
C(19)	.267
C(19.5)	.264
C(20)	.261
C(20.5)	.259
C(21)	.256
C(21.5)	.254
C(22)	.251
C(22.5)	.249
C(23)	.247
C(23.5)	.245
C(24)	.242
C(24.5)	.240
C(25)	.238
C(25.5)	.236
C(26)	.234
C(26.5)	.233
C(27)	.231
C(27.5)	.229
C(28)	.227
C(28.5)	.226
C(29)	.224
C(29.5)	.222
C(30)	.221
C(30.5)	.219
C(31)	.218
C(31.5)	.216
C(32)	.215
C(32.5)	.213
C(33)	.212
C(33.5)	.210
C(34)	.209
C(34.5)	.208
C(35)	.206
C(35.5)	.205
C(36)	.204
C(36.5)	.203
C(37)	.201
C(37.5)	.200
C(38)	.199
C(38.5)	.198
C(39)	.197
C(39.5)	.196
C(40)	.195
C(40.5)	.194
C(41)	.193
C(41.5)	.192
C(42)	.191
C(42.5)	.190
C(43)	.189
C(43.5)	.188
C(44)	.187
C(44.5)	.186
C(45)	.185
C(45.5)	.184
C(46)	.183
C(46.5)	.182
C(47)	.181
C(47.5)	.180
C(48)	.180
C(48.5)	.179
C(49)	.178
C(49.5)	.177
C(50)	.176
C(50.5)	.175
C(51)	.175
C(51.5)	.174
C(52)	.173
C(52.5)	.172
C(53)	.172
C(53.5)	.171
C(54)	.170
C(54.5)	.170
C(55)	.169
C(55.5)	.168
C(56)	.167
C(56.5)	.167
C(57)	.166
C(57.5)	.165
C(58)	.165
C(58.5)	.164
C(59)	.164
C(59.5)	.163
C(60)	.162

Table 12: Critical Values for Outlier Test (5% significance level, from Weisberg, 1980, p. 265)

T / K	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	20	25	30
6	4.85	6.23	10.89	76.39														
7	4.38	5.07	6.58	11.77	89.12													
8	4.12	4.53	5.26	6.90	12.59	101.9												
9	3.95	4.22	4.66	5.44	7.18	13.36	114.6											
10	3.83	4.03	4.32	4.77	5.60	7.45	14.09	127.3										
11	3.75	3.90	4.10	4.40	4.88	5.75	7.70	14.78	140.1									
12	3.69	3.81	3.96	4.17	4.49	4.98	5.89	7.94	15.44	152.8								
13	3.65	3.74	3.86	4.02	4.24	4.56	5.08	6.02	8.16	16.08	165.5							
14	3.61	3.69	3.79	3.91	4.07	4.30	4.63	5.16	6.14	8.37	16.69	178.2						
15	3.58	3.65	3.73	3.83	3.95	4.12	4.36	4.70	5.25	6.25	8.58	17.28	191.0					
16	3.56	3.62	3.68	3.77	3.87	4.00	4.17	4.41	4.76	5.33	6.36	8.77	17.85	203.7				
17	3.54	3.59	3.65	3.72	3.80	3.90	4.04	4.21	4.46	4.82	5.40	6.47	8.95	18.40	216.4			
18	3.53	3.57	3.62	3.68	3.75	3.83	3.94	4.08	4.26	4.51	4.88	5.47	6.57	9.13	18.93			
19	3.52	3.56	3.60	3.65	3.71	3.78	3.86	3.97	4.11	4.30	4.55	4.93	5.54	6.67	9.30			
20	3.51	3.54	3.58	3.62	3.67	3.73	3.81	3.89	4.00	4.15	4.33	4.59	4.98	5.60	6.76			
21	3.50	3.53	3.57	3.60	3.65	3.70	3.76	3.83	3.92	4.03	4.18	4.37	4.64	5.03	5.67			
22	3.50	3.52	3.55	3.59	3.63	3.67	3.72	3.78	3.86	3.95	4.06	4.21	4.40	4.68	5.08	280.1		
23	3.49	3.52	3.54	3.57	3.61	3.65	3.69	3.75	3.81	3.88	3.98	4.09	4.24	4.44	4.71	21.41		
24	3.49	3.51	3.53	3.56	3.59	3.63	3.67	3.71	3.77	3.83	3.91	4.00	4.12	4.27	4.47	10.07		
25	3.48	3.50	3.53	3.55	3.58	3.61	3.65	3.69	3.73	3.79	3.85	3.93	4.02	4.14	4.30	7.17		
26	3.48	3.50	3.52	3.54	3.57	3.60	3.63	3.66	3.70	3.75	3.81	3.87	3.95	4.05	4.17	5.95		
27	3.48	3.50	3.52	3.54	3.56	3.58	3.61	3.65	3.68	3.72	3.77	3.83	3.89	3.97	4.07	5.29	343.8	
28	3.48	3.50	3.51	3.53	3.55	3.58	3.60	3.63	3.66	3.70	3.74	3.79	3.84	3.91	3.99	4.88	23.63	
29	3.48	3.49	3.51	3.53	3.55	3.57	3.59	3.62	3.64	3.68	3.71	3.76	3.81	3.86	3.93	4.61	10.74	
30	3.48	3.49	3.51	3.52	3.54	3.56	3.58	3.60	3.63	3.66	3.69	3.73	3.77	3.82	3.88	4.42	7.53	
31	3.48	3.49	3.50	3.52	3.54	3.55	3.57	3.59	3.62	3.64	3.67	3.71	3.74	3.79	3.84	4.28	6.18	
32	3.48	3.49	3.50	3.52	3.53	3.55	3.57	3.59	3.61	3.63	3.66	3.69	3.72	3.76	3.80	4.17	5.47	407.4
33	3.48	3.49	3.50	3.52	3.53	3.54	3.56	3.58	3.60	3.62	3.64	3.67	3.70	3.74	3.77	4.08	5.03	25.66
34	3.48	3.49	3.50	3.51	3.53	3.54	3.56	3.57	3.59	3.61	3.63	3.66	3.68	3.71	3.75	4.01	4.74	11.34
35	3.48	3.49	3.50	3.51	3.52	3.54	3.55	3.57	3.58	3.60	3.62	3.64	3.67	3.70	3.73	3.96	4.53	7.84
36	3.48	3.49	3.50	3.51	3.52	3.54	3.55	3.56	3.58	3.60	3.61	3.63	3.66	3.68	3.71	3.91	4.37	6.39
37	3.48	3.49	3.50	3.51	3.52	3.53	3.55	3.56	3.57	3.59	3.61	3.62	3.65	3.67	3.69	3.87	4.26	5.62
38	3.48	3.49	3.50	3.51	3.52	3.53	3.54	3.56	3.57	3.58	3.60	3.62	3.64	3.66	3.68	3.84	4.16	5.16
39	3.49	3.49	3.50	3.51	3.52	3.53	3.54	3.55	3.57	3.58	3.59	3.61	3.63	3.65	3.67	3.81	4.09	4.84
40	3.49	3.49	3.50	3.51	3.52	3.53	3.54	3.55	3.56	3.58	3.59	3.60	3.62	3.64	3.66	3.79	4.03	4.62
50	3.51	3.51	3.51	3.52	3.53	3.53	3.54	3.54	3.55	3.56	3.57	3.57	3.58	3.59	3.60	3.66	3.75	3.88
60	3.53	3.53	3.53	3.54	3.54	3.54	3.55	3.55	3.56	3.56	3.57	3.57	3.58	3.58	3.59	3.62	3.67	3.73
70	3.55	3.55	3.55	3.55	3.56	3.56	3.56	3.56	3.57	3.57	3.57	3.58	3.58	3.59	3.59	3.61	3.64	3.67
80	3.57	3.57	3.57	3.57	3.57	3.58	3.58	3.58	3.58	3.58	3.59	3.59	3.59	3.60	3.60	3.61	3.63	3.66
90	3.58	3.59	3.59	3.59	3.59	3.59	3.59	3.60	3.60	3.60	3.60	3.60	3.60	3.61	3.61	3.62	3.63	3.65
100	3.60	3.60	3.60	3.60	3.61	3.61	3.61	3.61	3.61	3.61	3.61	3.62	3.62	3.62	3.62	3.63	3.64	3.65
200	3.73	3.73	3.73	3.73	3.73	3.73	3.73	3.73	3.73	3.73	3.73	3.73	3.73	3.73	3.74	3.74	3.74	3.74
300	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.81	3.82	3.82	3.82	3.82	3.82	3.82	3.82	3.82
400	3.87	3.87	3.87	3.87	3.87	3.87	3.87	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88
500	3.92	3.92	3.92	3.92	3.92	3.92	3.92	3.92	3.92	3.92	3.92	3.92	3.92	3.92	3.92	3.92	3.92	3.92

APPENDIX b

Sample data

CD	Durable Consumption/real P76
YD$	Disposable Income/nom.
RPR	Prime-Rate/Austria
PC	Deflator/Private Consumption 1976=100
DTP72	Dummy Tax-Policy 1972
DTP77	Dummy Tax-Policy 1977

	CD	YD$	RPR	PC	DTP72	DTP77
65	25.660	157.995	7.800	56.214	.000	.000
66	28.600	171.178	7.805	57.538	.000	.000
67	28.967	183.530	7.784	59.813	.000	.000
68	30.163	196.539	7.235	61.333	.000	.000
69	29.915	210.707	7.175	63.528	.000	.000
70	33.648	233.138	8.223	66.371	.000	.000
71	40.295	260.896	8.206	69.678	.000	.000
72	47.568	285.940	8.500	74.197	1.000	.000
73	46.729	317.359	8.500	79.081	.000	.000
74	46.825	359.999	12.563	86.999	.000	.000
75	49.879	408.802	10.271	93.859	.000	.000
76	52.964	457.829	8.542	100.000	.000	.000
77	63.623	496.444	8.875	105.372	.000	1.000
78	50.728	528.546	9.104	109.929	.000	.000
79	55.028	576.513	8.188	114.788	.000	.000
80	54.154	618.949	11.000	122.269	.000	.000
81	52.569	654.256	13.083	131.064	.000	.000
82	53.765	707.700	12.600	138.762	.000	.000

HBU	Average Working Time/Hours per Week
NAZ	Legal Working Time/Hours per Week
GDP	Gross domestic Product/real P76
GDPS	Gross domestic Product-Trend-Values

	HBU	NAZ	GDP	GDPS
66	42.000	45.000	475.523	473.562
67	41.600	45.000	489.009	495.290
68	41.900	45.000	509.115	518.015
69	41.800	45.000	536.937	541.782
70	40.800	43.000	571.472	566.640
71	40.400	43.000	600.686	592.638
72	39.600	42.000	637.985	649.464
73	39.600	42.000	669.162	667.272
74	39.700	42.000	695.551	685.569
75	38.300	40.000	693.029	704.367
76	37.800	40.000	724.747	723.680
77	37.700	40.000	756.343	743.523
78	37.600	40.000	760.265	763.911
79	37.600	40.000	796.571	784.857
80	37.200	40.000	822.066	806.378
81	36.800	40.000	822.431	828.488

BU13	Employment/Construction Sector	
QNP13R	Real Output/Construction Sector	P76
TIME	Trendvariable	
D7290	Dummy 1972-1990	

	BU13	QNP13R	TIME	D7290
66	257.500	39.960	66.000	.000
67	251.400	41.379	67.000	.000
68	240.500	42.941	68.000	.000
69	238.400	44.323	69.000	.000
70	236.000	46.098	70.000	.000
71	242.800	51.495	71.000	.000
72	253.700	54.903	72.000	1.000
73	266.100	57.859	73.000	1.000
74	263.100	59.833	74.000	1.000
75	254.800	59.025	75.000	1.000
76	252.900	59.179	76.000	1.000
77	258.900	61.405	77.000	1.000
78	258.500	60.749	78.000	1.000
79	255.300	60.889	79.000	1.000
80	250.400	60.825	80.000	1.000

CDQ	Durable Consumption/real P76
YD$Q	Disposable Income/nom.
RPRQ	Prime-Rate/Austria
PCQ	Deflator/Private Consumption 1976=100
DTP724	Dummy Tax-Policy 1972.4
DTP774	Dummy Tax-Policy 1977.4

	CDQ	YD$Q	RPRQ	PCQ	DTP724	DTP774
66Q1	5.577	37.960	7.800	56.731	.000	.000
66Q2	7.121	42.600	7.800	57.539	.000	.000
66Q3	7.093	45.140	7.800	58.206	.000	.000
66Q4	8.809	47.260	7.818	57.537	.000	.000
67Q1	5.909	40.040	7.855	59.263	.000	.000
67Q2	7.039	46.280	7.844	60.063	.000	.000
67Q3	6.720	47.630	7.787	60.046	.000	.000
67Q4	9.299	51.590	7.651	59.814	.000	.000
68Q1	6.183	43.620	7.427	60.481	.000	.000
68Q2	7.450	49.340	7.264	61.589	.000	.000
68Q3	8.295	51.100	7.159	61.565	.000	.000
68Q4	8.235	54.800	7.092	61.554	.000	.000
69Q1	5.355	46.760	7.055	62.928	.000	.000
69Q2	7.299	53.580	7.053	63.795	.000	.000
69Q3	7.479	55.200	7.157	64.018	.000	.000
69Q4	9.782	57.650	7.434	63.309	.000	.000
70Q1	6.359	51.520	7.831	65.136	.000	.000
70Q2	8.244	59.090	8.170	66.654	.000	.000
70Q3	8.311	59.390	8.415	67.136	.000	.000
70Q4	10.734	63.140	8.474	66.372	.000	.000
71Q1	8.099	58.570	8.334	68.692	.000	.000
71Q2	10.034	64.620	8.193	69.385	.000	.000
71Q3	9.832	68.200	8.107	70.480	.000	.000
71Q4	12.330	69.510	8.192	69.920	.000	.000
72Q1	9.181	63.180	8.500	72.136	.000	.000
72Q2	11.226	70.560	8.500	74.197	.000	.000
72Q3	11.083	73.470	8.500	75.057	.000	.000
72Q4	16.078	78.730	8.500	74.957	1.000	.000
73Q1	9.252	70.990	8.500	76.884	.000	.000
73Q2	11.449	79.060	8.500	78.426	.000	.000
73Q3	11.308	79.440	8.500	79.396	.000	.000
73Q4	14.720	87.870	8.500	80.983	.000	.000
74Q1	10.114	81.380	8.500	83.920	.000	.000
74Q2	11.425	90.070	11.750	86.277	.000	.000
74Q3	11.332	90.580	15.000	87.692	.000	.000
74Q4	13.954	97.970	15.000	89.468	.000	.000

	CDQ	YD$Q	RPRQ	PCQ	DTP724	DTP774
75Q1	10.475	90.290	11.833	91.774	.000	.000
75Q2	11.472	101.760	9.917	93.461	.000	.000
75Q3	11.771	104.700	9.750	94.606	.000	.000
75Q4	16.161	112.650	9.583	95.163	.000	.000
76Q1	10.964	100.550	8.917	98.173	.000	.000
76Q2	12.341	114.030	8.750	99.582	.000	.000
76Q3	12.817	116.720	8.250	101.191	.000	.000
76Q4	16.842	126.530	8.250	100.689	.000	.000
77Q1	12.343	110.810	8.250	104.401	.000	.000
77Q2	13.679	126.200	8.417	105.372	.000	.000
77Q3	14.633	124.770	9.250	106.219	.000	.000
77Q4	22.968	134.660	9.583	105.372	.000	1.000
78Q1	9.639	117.970	9.750	108.948	.000	.000
78Q2	12.529	135.530	9.333	109.930	.000	.000
78Q3	12.682	133.740	8.583	110.798	.000	.000
78Q4	15.878	141.310	8.750	109.929	.000	.000
79Q1	12.216	130.550	8.250	113.265	.000	.000
79Q2	13.867	146.210	8.000	114.314	.000	.000
79Q3	13.317	144.850	8.000	115.706	.000	.000
79Q4	15.628	154.900	8.500	115.604	.000	.000
80Q1	12.455	142.390	9.167	120.143	.000	.000
80Q2	13.647	157.870	11.167	121.761	.000	.000
80Q3	13.160	154.300	11.333	123.243	.000	.000
80Q4	14.892	164.390	12.333	123.589	.000	.000
81Q1	11.394	150.240	12.500	129.153	.000	.000
81Q2	13.476	165.680	12.833	130.052	.000	.000
81Q3	12.783	161.430	13.500	132.061	.000	.000
81Q4	14.916	176.910	13.500	132.621	.000	.000
82Q1	11.804	161.430	13.500	137.114	.000	.000
82Q2	13.759	181.000	12.933	138.140	.000	.000
82Q3	13.256	175.450	12.200	140.029	.000	.000
82Q4	14.946	189.820	11.767	139.531	.000	.000

Aggregated Data:

YD = YD$/PC*100
YDQ = YD$Q/PCQ*100
RR = RPR - 100*(PC/PC[1]-1)
RRQ = RPRQ - 100*(PCQ/PCQ[4]-1)