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UNIVARIATE PROPERTIES OF THE KOREAN ECONOMIC TIME SERIES*

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This paper studies univariate properties of the Korean economic time series. The null hypothesis of a unit root is tested for each series by using the augmented Dickey-Fuller, Phillips-Perron and Durbin-Hausman tests. It is found that the null of a unit root cannot be rejected for most of the series. The confidence interval for the sum of AR coefficients is also calculated for each series. Most of the computed confidence intervals include 1, which coincides with the unit root test results. Some implications of the presence of a unit root for forecasting and structural regressions are discussed.

I. INTRODUCTION

Since the influential work of Nelson and Plosser (1982), much attention has been paid to the presence of a unit root for macroeconomic time series. The presence of a unit root has often been interpreted as evidence in support of the real business cycle theory or the efficient market hypothesis. Besides these economic interpretations, the presence of a unit root is important for subsequent statistical analyses in the sense that a standard regression theory based on the law of large numbers and central limit theorem cannot be applied when the regressor is a process with a unit root (integrated process). The reason for this is that the asymptotic negligibility condition which is essential for the law of large numbers and central limit theorem [see, for example, Hall and Heyde (1980)] is not satisfied by integrated processes. Hence, when we deal with variables with a unit root, we need a different econometric theory which is more involved and based on the functional central limit theorem. Park and Phillips (1988, 1989) provide extensive analyses regarding the regressions with integrated processes.

While extensive test results demonstrating the presence of a unit root in the

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US economic times series have been accumulating for the last decade, formal unit root tests for the Korean economic time series have been scarce. Thus, the first objective of this paper is to.test the Korean economic time series for a unit root. In light of the importance of the presence of a unit root for subsequent regression analyses, these test results will be the cornerstone for further data analyses. We will study 28 quarterly and 20 monthly data provided by the Korea Development Institute. The methods we are to use are the augmented Dickey-Fuller [cf. Dickey and Fuller (1979), Nelson and Plosser (1982) and Said and Dickey (1984)], Phillips-Perron [cf. Phillips (1987) and Phillips and Perron (1988)] and Durbin-Hausman [cf. Choi (1990a,1992)] tests. The augmented Dickey-Fuller and Phillips-Perron tests has been most commonly used for applications. The Durbin-Hausman test is relatively new, but shows good finite sample performance.

The second objective of this paper is to provide confidence intervals for the sum of AR coefficients for the Korean economic time series. This will provide additional information regarding the presence of a unit root. The method we are to use is developed in Choi (1993).

The structure of this paper has been planned as follows. Section II explains the methods for the inference on a unit root and for calculating the confidence interval for the sum of AR coefficients. Section III reports the empirical results for the Korean economic time series. The null of a unit root is tested and the confidence interval for the sum of AR coefficients is computed for each series. Section IV considers the implications of the presence of a unit root for forecasting and structural regressions. A few illustrations of the cointegration test based on the Durbin-Hausman procedure are also given. Section V contains a summary and further remarks.

II. METHODOLOGY

2.1. Inference on a unit root

In this subsection, we briefly explain the augmented Dickey-Fuller, Phillips -Perron, and Durbin-Hausman tests which we will use in this paper. Other than these methods, there are many different test statistics for the inference on a unit root. The reader is referred to Diebold and Nerlove (1990) and Campbell and Perron (1991) for excellent reviews on this subject.

The three tests are concerned with the models

$$y_t = \alpha y_{t-1} + u_t,\ (t = 1,2,...,T),$$

$$(1)\quad y_t = \mu_0 + \alpha y_{t-1} + u_t,\ (t = 1,2,...,T)$$

and

$$(2)\ y_t = \mu_0 + \mu_1 t + \alpha y_{t-1} + u_t,\ (t = 1,2,\ldots,T),$$

where $\{u_t\}$ denotes a stationary sequence of errors. The null of the three tests is H_0: $\alpha=1$, and the alternative is H_1: $|\alpha|<1$. We shall confine our attention to models (1) and (2), because many macroeconomic time series display nonzero mean and/or linear time trends. We test the null hypothesis under the restrictions $\mu_0=0$ and $\mu_1=0$ for models (1) and (2), respectively. Thus, under the null $y_t=y_{t-1}+u_t$ for model (1), and $y_t=\mu_0+y_{t-1}+u_t$ for model (2).

The augmented Dickey-Fuller and Phillips-Perron tests are basically extensions of the Dickey-Fuller procedure [cf. Dickey and Fuller (1979)] to the case of serially correlated errors. The augmented Dickey-Fuller tests assume that the errors follow the stationary and invertible ARMA(p, q) process of unknown order and use the long autoregression to deal with the serial correlation in errors. Formally, the augmented Dickey-Fuller tests are the standard t-ratios for the OLS estimate $\hat{\alpha}$ in the regressions

$$(3)\ \Delta y_t = \hat{\mu}_0 + \hat{\alpha} y_{t-1} + \sum_{i=2}^{p} \hat{\beta}_i \Delta y_{t-i+1} + \hat{v}_{tp}$$

and

$$(4)\ \Delta y_t = \hat{\mu}_0 + \hat{\mu}_1 t + \hat{\alpha} y_{t-1} + \sum_{i=1}^{p} \hat{\beta}_i \Delta y_{t-i} + \hat{v}_{tp},$$

where $\Delta y_t=y_t-y_{t-1}$ and it is required that $p\to\infty$ as $T\to\infty$ and $p=O_P(T^{1/3})$ [see Said and Dickey (1984) for formal proofs of these requirements]. The limiting null distributions of the t-ratios for regressions (3) and (4) are nonnormal and tabulated by simulation methods in Fuller (1976, p.373). Under the alternative of stationarity, the augmented Dickey-Fuller tests diverge at the rate $O_P(T^{1/2})$. We reject the null hypothesis when the computed value of the t-ratios is less than the corresponding critical value.

The Phillips-Perron procedure takes a nonparametric approach and assumes that $\{u_t\}$ is a mixing sequence which satisfies some general conditions that allow for a weakly dependent and heterogeneously distributed innovations sequence. This nonparametric treatment of the innovations sequence is advantageous because it is not necessary to be explicit about the dynamic specifications of the innovations. For model (1), the Phillips-Perron coefficient test is defined as

$$(5)\ \hat{Z}_\alpha = T(\hat{\alpha} - 1) - (1/2)(s_{Tl}^2 - s^2)(T^{-2}X_1{}'X_1)_{22}^{-1},$$

where $\hat{\alpha}$ is the OLS estimate, X_1 denotes the regressor matrix,

$$s^2 = T^{-1}\sum_{t=1}^{T}\hat{u}_t^2,$$

and

$$s_{Tl}^2 = T^{-1}\sum_{t=1}^{T}\hat{u}_t^2 + 2T^{-1}\sum_{s=1}^{l} w_{sl} \sum_{t=s+1}^{T} \hat{u}_t\hat{u}_{t-s}$$

for some choice of lag window w_{sl}. We will use the Parzen window for the applications reported in Section III, following Phillips and Perron (1988). Comprehensive analyses regarding the choice of lag window and truncation parameter are given in Andrews (1989). For model (2), the Phillips-Perron test is similarly defined except that we use the regressor matrix corresponding to model (2). The limiting null distributions of the Phillips-Perron tests are nonnormal and tabulated by simulation in Fuller (1976, p. 371). The Phillips-Perron coefficient tests diverge at the rate $O_P(T)$ under the alternative of stationarity. Phillips and Perron (1988) also propose the t-ratio tests for a unit root, but this diverges at a slower rate $[O_P(T^{1/2})]$ under the alternative than the coefficient test, and hence we will apply only the coefficient tests. In practice, we reject the null when the computed value of the Phillips-Perron tests is less than the corresponding critical value.

Finite sample performance of the augmented Dickey-Fuller and Phillips-Perron tests has been compared by simulation methods in various articles. It is shown in Phillips and Perron (1988) that the Phillips-Perron coefficient tests perform better that the augmented Dickey-Fuller tests when the errors follow the moving average process. In contrast, DeJong, Nankervis, Savin and Whiteman (1990) find that the augmented Dickey-Fuller tests perform better in finite samples than the Phillips-Perron coefficient tests when the errors follow the autoregressive process. Unfortunately, however, these simulation results indicate that both tests are not powerful at moderate sample sizes, and hence that empirical results using these tests should be interpreted with caution. This is especially so for model (2), because the limiting null distributions of the estimates of the AR coefficient shift to the left as we include higher order time polynomials in the autoregressive model, which makes it more and more difficult to distinguish the null distribution from the distributions under the alternative.

The Durbin-Hausman tests are relatively new and do not have the same asymptotic distributions as the Dickey-Fuller tests. These are also based on the assumption of mixing errors as the Phillips-Perron tests. In order to introduce the Durbin-Hausman tests, we need to define the pseudo instrumental variable estimators, which are obtained by using $\{1, y_t\}$ as an instrument for model (1), and $\{1, t, y_t\}$ for model (2). We denote the pseudo instrumental estimator as $\hat{\alpha}_{IV}$. This estimator is different from the usual instrumental variable estimator, in the sense that the current variable y_t is used as an instrument. The Durbin-Hausman test for model (1) is defined as follows:

$$(6)\ HMS = (\hat{\alpha}_{IV} - \hat{\alpha})^2 / \{\hat{\delta}\hat{s}^2[X_1{}'X_1]_{22}^{-1}\},$$

where $\hat{\alpha}$ is the OLS estimate, $\hat{\delta} = \hat{s}^2/\hat{s}_{Tl}^2$, and $\hat{s}^2$, $\hat{s}_{Tl}^2$ and X_1 are defined as for equation (5). The Durbin-Hausman test for model (2) is defined analogously by using the regressor matrix corresponding to model (2). The limiting distributions of the Durbin-Hausman tests are nonnormal and tabulated by simulation in Choi (1992). Unlike the augmented Dickey-Fuller and Phillips-Perron tests, we reject the null when the computed values of the Durbin-Hausman tests are greater than the corresponding critical values. The Durbin-Hausman tests diverge at the same rate as the Phillips-Perron coefficient tests under the alternative of stationarity.

Finite sample performance of the Durbin-Hausman tests are investigated in Choi (1990a, 1992). In the case of *iid* errors, the Durbin-Hausman tests show higher power than the Dickey-Fuller tests in finite samples, as shown in Choi (1992). The Durbin-Eausman tests also show good finite sample performance for serially correlated errors, as simulation results in Choi (1990a) indicate. However, it needs to be borne in mind that the performance of the Durbin-Hausman tests deteriorates if we include a linear time trend in the autoregression model as in the case of the augmented Dickey-Fuller and Phillips-Perron tests. Hence, the power problem of unit root tests cannot be completely overcome by this new approach, even though we observe that the Durbin-Hausman procedure improves the Dickey-Fuller approach in terms of finite sample power performance.

2.2. Confidence interval for AR(p) processes

We explain the methods of obtaining the asymptotic confidence interval for the sum of AR coefficients in this subsection. The model we consider is

$$\begin{aligned} y_t &= \alpha_1 y_{t-1} + \alpha_2 y_2 + \ldots + \alpha_P y_{t-P} + e_t \\ &= \delta_1 y_{t-1} + \sum_{j=2}^{P} \delta_j (y_{t-j+1} - y_{t-j}) + e_t, \end{aligned}$$

where $\delta_1 = \sum_{j=1}^{p} a_j$, $\delta_i = -\sum_{j=1}^{p} a_j (i \geq 2)$ and p is assumed to be known. If there is a unit root, $\delta_1 = 1$. Otherwise $\delta_1 < 1$. Hence, the confidence interval for δ_1 provides useful information regarding the location of the characteristic roots along with statistical inference on a unit root. However, when there is a unit root, calculating the asymptotic confidence interval for the sum of AR coefficients is non-trivial, since the limiting distribution of the OLS estimate for δ_1 is nonnormal. Further, even if we obtain the confidence interval, it is not-meaningful, for it is based on the prior knowledge that there is a unit root. In other words, the discontinuity in the asymptotic distribution theory precludes us from obtaining a meaningful confidence interval for δ_1. This is pointed out in Sims (1988) in a simpler context and has been used as one of the main arguments favoring the Bayesian approach over the classical approach.

However, it is possible to restore continuity in the asymptotic distribution theory for the OLS estimate of δ_1 by using the classical approach. That is, we consider the augmented regression model

$$y_t = \delta_1 y_{t-1} + \sum_{j=2}^{p} \delta_j \Delta y_{t-j+1} + \delta_{p+1} y_{t-p-1} + e_t,$$

where $\delta_{p+1} = 0$ by construction. For this regression model, the OLS estimates of the coefficients converge in distribution to normal variates for both $|\alpha| < 1$ and $\alpha = 1$, and hence there is no discontinuity in asymptotic distribution theory. In particular, we have for $|\alpha| < 1$ and $\alpha = 1$

$$(7)\ t(\hat{\delta}_1) \Rightarrow N(0,\ 1) \text{ as } T \rightarrow \infty,$$

where "$\Rightarrow$" denotes the convergence in distribution. Details of these results are proven in Choi (1993). Thus, the asymptotic confidence interval for $\hat{\delta}_1$ is constructed trivially as $[\hat{\delta}_1 - c_\alpha std(\hat{\delta}_1),\ \hat{\delta}_1 + c_\alpha std(\hat{\delta}_1)]$ where, for example, c_α = 1.96 for 95% confidence intervals. Note that we may detrend the series before we compute confidence intervals, because (7) is invariant to detrending as explained in Choi (1993).

III. EMPIRICAL RESULTS

We investigate the major Korean macroeconomic time series in this section. First, we test the series for a unit root by using the augmented Dickey-Fuller, Phillips-Perron, and Durbin-Hausman tests. Next, we estimate a 95% confidence interval for the sum of AR coefficients for each series. The data we study are described in Appendix 1. All the data are deseasonalized and taken natural logs except such price variables as exchange rates and interest rates.

3.1. Testing for a unit root

We report the results of unit root tests at the 5% significance level in Appendix 2. For the augmented Dickey-Fuller, we used the lag length 2, 3 and 4. The lag length for the long-run covariance estimates which are required to construct the Phillips-Perron and Durbin-Hausman tests were set at 2, 3, and 4. As the graphs of the series [see Appendix 4] indicate, we observe strong trend components for almost all the series. Thus, for most of the series, we report the test results using model (2) only. For some price variables, the trend component is not obviously seen, so for these series we also report the results using model (1). Testing the significance of trend variables is also possible, but here we confine ourselves to testing for a unit root.

We find that the null of a unit root can not be rejected by all three tests for all the series except for *CG, GNPA, IFC, MOP, MOED, VCOD,* and *BCP.* For *CG,* only the Durbin-Hausman test rejects the null. For *GNPA, IFC,* and *MOP,* the Phillips-Perron and Durbin-Hausman tests reject the null, but the augmented Dickey-Fuller test does not. The null hypothesis is rejected for the series *MOED, VCOD,* and *BCP* by the augmented Dickey-Fuller test at lag length 2, the Phillips-Perron test, and the Durbin-Hausman test. Test results using model (1) provide the unanimous results: the null of a unit root cannot be rejected by the three tests for these price variables. We discover from these results that most macroeconomic series seem to contain a unit root. In other words, most of the series are well represented as an integrated process with drift

$$y_t = \mu_0 t + \sum_{i=1}^{t} u_i + y_0$$

or as a pure integrated process

$$y_t = \sum_{i=1}^{t} u_i + y_0,$$

where $\{u_t\}$ is a stationary sequence. Ignoring the presence of a unit root may induce seriously wrong statistical results regarding inference and forecasting, as will be discussed in Section IV.

3.2. Confidence interval

Confidence interval provides additional information regarding the presence of a unit root other than hypothesis testing. Before calculating confidence intervals, we demeaned and detrended the series by using the OLS regression

$$y_t = \hat{\beta}_0 + \hat{\beta}_1 t + \overline{y}_t$$

The series $\{\overline{y}_t\}$ were used to compute the confidence intervals. Note that the coefficient estimates $\hat{\beta}_0$ and $\hat{\beta}_1$ converge to the true values in probability, though they are not asymptotically normal when y_t contains a unit root. The results for the confidence intervals we obtained are reported in Appendix 3 and approximately coincide with the test results in Appendix 2. There is strong evidence against the presence of a unit for the series *GNPA*, *MOP*, *MOED*, *VCOD*, and *BCP* according to the computed confidence intervals. The confidence intervals of the series *CG* and *IFC* either contain 1 or do not contain 1 depending on the lag selection. There are some series for which confidence intervals do not contain 1 for some lag lengths (e.g., *IFM*, *LEA*, *M*, etc.). For these dubious cases, we need to be more careful about the lag selection for AR processes, because the confidence intervals we compute are based on the assumption that the the AR lag length is known. When the AR lag length is selected improperly, the confidence interval is likely to yield misguided information about the location of the sum of AR coefficients. For nominal price variables, we also report the confidence interval based on the demeaned series $\{\tilde{y}_t\}$ from the regression

$$y_t = \hat{\beta}_0 + \tilde{y}_t.$$

The confidence intervals for all the series contain 1 except *RD* at $p=3$.

IV. IMPLICATIONS FOR FURTHER ECONOMETRIC ANALYSES

(1) Univariate forecasting

Univariate ARMA models are frequently used for forecasting. However, when there is a unit root, the mean squared error of prediction diverges as forecasting horizon becomes infinite, and hence long-term forecasting results are not reliable in such a case. Hence, we need to be careful about interpreting the long-term ARMA forecasting results regarding the Korean economic time series, because it seems that many of them have a unit root as we have seen in Section III For the univariate predictions in the presence of unit roots, see Fuller and Hasza (1979, 1981). In addition, Samaranayake and Hasza (1988) deal with the multivariate prediction in the presence of a unit root.

(2) Danger of spurious regressions

When we regress one integrated process on others, special care needs to be taken, because we are often unable to reject the null of no statistical relation from these regressions even when the regressors and regressand have no statistical relations. Granger and Newbold (1976) call this practice of regressing one integrated process on other unrelated integrated processes "spurious regression," and study properties of major statistics from this regression by means of simulation. The spurious regressions are further analyzed in Phillips (1986) and Choi (1991). Major characteristics of the spurious regressions are high R^2, low Durbin-Watson, and high t and F values. The spurious regressions yield not only wrong inferential results, but also high prediction errors. The one-step prediction error from the spurious regression

$$y_t = \hat{a}x_t + \hat{u}_t, \ (t = 1,2,...,T)$$

is

$$y_{T+1} - \hat{y}_{T+1} = -(\hat{a} - a)' x_{T+1} + u_{T+1}.$$

Since $\hat{a} = O_P(1)$ in the spurious regressions and $x_{T+1} = O_P(T^{1/2})$, we have

$$y_{T+1} - \hat{y}_{T+1} = O_P(T^{1/2})$$

which implies that the prediction error diverges as $T \rightarrow \infty$. Thus, when a seemingly well-fitted regression model yields poor prediction performance, there is a good reason to suspect that the regression is spurious in the sense of Granger and Newbold (1976).

(3) Cointegrating regression analyses

When integrated processes have a meaningful statistical relation in the sense that some linear combinations of the integrated processes are weakly stationary, the processes are said to be cointegrated in the sense of Engle and Granger (1987). Once we confirm statistically that individual series have a unit root, the next step we need to take is to study the cointegrating relations among the variables we are interested in. When the integrated processes are cointegrated, we may interpret that the cointegrating vector represents equilibrium relation and that equilibrium occasionally occurs. Testing whether there exist cointegrating relations among economic variables has been an important issue in econometrics, and various testing methods have been developed. The simplest method is to test for a unit root in the residuals from the structural regressions. Several residual-based tests are proposed in Engle and Granger (1987), Phillips and Ouliaris (1988), and Choi (1990b). It is important to remember, however, that the null is no-cointegration for the residual-based tests. When the null is proposed as cointegration, there is a problem of inconsistency for test statistics [see Phillips and Ouliaris (1988) for this]. Besides the residual-based tests, there are other methods for testing the number of cointegrating vectors [see Johanson (1988) and Stock and Watson (1988), for example].

In what follows, we illustrate how we test for cointegration. The method we use is the Durbin-Hausman test [see Choi (1990b)], which is based on regression residuals. Simulation results reported in Choi (1990b) show that the Durbin-Hausman tests are more powerful than the augmented Dickey-Fuller and Phillips' $\hat{Z}_a$ tests in finite samples. We investigate whether the interest rate in unorganized market (*RUM*) and time deposit rate (*RD*) are cointegrated. The OLS regression results using *RD* as a regressor are

$$RUM_t = \underset{(0.039)}{2.310}\, RD_t + \hat{u}_t, \quad R^2 = 0.977,$$

where the number in the parenthesis is the standard deviation. We run the AR(1) regression using the residual process $\{\hat{u}_t\}$

$$\hat{u}_t = 0.814\, \hat{u}_{t-1} + \hat{k}_t.$$

We may calculate the Durbin-Hausman statistic using equation (6) and the results from this regression. Note that we use $\{\hat{u}_t\}$ as an instrument to calculate the pseudo IV estimator. The computed values for the Durbin-Hausman test are 40.93, 40.02, 39.50, and 39.41 at lag lengths 2, 3, 4, and 5, respectively. Since the critical value of the Durbin-Hausman test at the 5% level is 33.19 [see Choi (1990b) for critical values], we reject the null of no cointegration at the 5% level. We obtain a similar result when *RUM* is used as a regressor. The OLS regression results in such case are

$$RD_t = \underset{(0.007)}{0.423}\, RUM_t + \hat{u}_t, \quad R^2 = 0.977,$$
$$\hat{u}_t = 0.814\, \hat{u}_{t-1} + \hat{k}_t,$$

and the value of the Durbin-Hausman tests are 41.09, 40.36, 39.96, and 39.94 at lag lengths 2, 3, 4, and 5, respectively. Hence, we reject the null of no cointegration at the 5% level. We may deduce from these statistical results that *RUM* and *RD* move together over the long run, though individual series appear to wander widely.

V. SUMMARY AND FURTHER REMARKS

We have studied the univariate properties of the Korean economic time series. Using the three methods of testing for a unit root, we could not reject the null hypothesis of a unit root for most of the series. Confidence intervals for the sum of AR coefficients were also calculated. This evidences coincide with the unit root test results for most of data we studied. We deduce from all these results that the Korean economic time series are well represented as integrated processes with or without drift. The standard practice of model building and forecasting needs to be reconsidered given this evidence: there are dangers of high mean squared error for long-run ARMA forecasting and of spuriousness for structural regressions. The main message of our statistical results is that further study on cointegrating relations among the Korean economic time series is needed in order to discover stable long-run relations among them. This will allow us to have better understanding regarding the long-run movements of economic variables and sounder structural models for forecasting.

Appendix 1 : Data description

1.1. quarterly data

Abbrev.	Data	Unit
C	Total consumption (r)	85' bil. won
CG	Government consumption (r)	85' bil. won
*CP*1	Household consumption (r)	85' bil. won
*CP*2	Private non-profit inst. consumption (r)	85' bil. won
CPI	Consumer price index	85'=100
E	Exchange rate W/$ (n)	won
GDP	Gross domestic product (r)	85' bil. won
GNP	Gross national product (r)	85' bil. won
GNPA	Agricultural value added (r)	85' bil. won
IF	Total fixed investment (r)	85' bil. won
IFC	Fixed investment of construction (r)	85' bil. won
IFM	Fixed investment of total equipment (r)	85' bil. won
LE	Total employment	1,000 per.
LEA	No. of per. employed in agricultural sector	1,000 per.
M	Imports of goods and services (r)	85' bil. won
*M*2	Money supply (n)	bil. won
MG	Imports of goods and services (r)	85' bil. won
MGSV	Commodity imports (n)	mil. US dol.
PMGS	Unit value index for commodity imports	85'=100
PXGS	Unit value index for commodity exports	85'=100
RD	Time deposit rate	% per annum
RUM	Interest rate for unorganized money market	% per annum
WM	Month. earning per per. in mfr. sector (n)	won
WPI	Wholesale price index	85'=100
X	Exports of goods and services (r)	85' bil. won
XG	Commodity exports (r)	85' bil. won
XGSV	Commodity exports (n)	mil. US dol.
YCB	Yields on corporate bonds	

Notes:

(1) The sampling period for all the data except *YCB* is 70':01-90':04. For *YCB*, it is 72:02-90:04.

(2) r denotes a real variable, and n a nominal one.

1.2. Monthly data

Abbrev.	Data	Sampling period	Unit
III	Industrial inventory index	70':01-91':05	85'=100

IPI	Industrial production index	70':01-91':05	85'=100
ISI	Industrial shipment index	70':01-91':05	85'=100
MOP	Machinery import license (n)	80':01-91':04	1,000 US dol.
MOED	Machinery orders: domestic (n)	80':01-91':05	mil. won
VCOD	Construction orders: domestic (n)	80':01-91':05	mil. won
BCP	Building construction permits	70':01-91':04	1,000 m^2
RTI	Retail trade index	70':01-91':05	85'=100
WRTI	Wholesale and retail trade index	70':01-91':05	85'=100
WTI	Wholesale trade index	70':01-91':05	85'=100
EPI	Export price index	71':01-91':06	85'=100
MPI	Import price index	71':01-91':06	85'=100
AW	Monthly average wage (n)	70':01-91':04	won
M1V	M1(n)	70':01-91':06	bil. won
MC	Imports: custom base (n)	71' 01-91' 06	mil. US dol.
XC	Exports: custom base (n)	71' 01-91' 06	mil. US dol.
LC	L/C arrived (n)	71':01-91':06	mil. US dol.
IL	I /L issued (n)	71' 01-91' 06	mil. US dol.
RKO	Exchange rate of Korea (n)	84':01-91':05	won/$
RJA	Exchange rate of Japan (n)	84':01-91':05	yen /$

Appendix 2 : Test results

2.1. Results using model (2)

Data	T	$ADF2$	$ADF3$	$ADF4$	$\hat{Z}_\alpha(2)$	$\hat{Z}_\alpha(3)$	$\hat{Z}_\alpha(4)$	$HMS(2)$	$HMS(3)$	$HMS(4)$
C	84	-0.52	-0.94	-1.02	-1.72	-1.15	-1.27	10.72	9.52	9.77
CG	84	-1.91	-1.55	-1.48	-20.50	-18.67	-18.17	72.47	65.68	63.79
*CP*1	84	-0.99	-0.93	-1.38	-4.77	-4.13	-4.14	16.17	14.70	14.73
*CP*2	84	-1.93	-2.03	-2.85	-7.22	-7.44	-7.65	16.38	16.91	17.40
CPI	84	-0.93	-1.19	-0.87	0.17	-0.09	-0.30	1.63	2.13	2.55
E	84	-1.22	-1.89	-1.67	-0.27	-0.81	-1.28	4.29	5.39	6.32
GDP	84	-2.30	-1.83	-2.11	-13.28	-12.23	-12.36	32.90	29.83	30.21
GNP	84	-1.99	-1.77	-1.98	-9.58	-8.76	-8.99	23.05	20.90	21.39
GNPA	84	-3.17	-2.85	-2.64	-39.47	-37.74	-38.92	238.2	224.2	233.7
IF	84	-1.91	-2.24	-2.07	-10.12	-9.51	-9.46	25.32	23.70	23.59
IFC	84	-2.52	-2.71	-2.87	-27.76	-25.98	-25.92	111.7	103.1	102.8
IFM	84	-1.78	-2.26	-1.50	-10.04	-8.75	-8.27	23.95	20.53	19.24
LE	84	-1.74	-1.69	-2.04	-9.86	-8.67	-7.94	20.28	16.00	15.21
LEA	84	-1.84	-2.06	-2.39	-10.84	-9.49	-8.88	17.41	13.70	12.04
M	84	-2.08	-2.21	-1.92	-9.22	-8.54	-8.37	19.94	18.20	17.76
*M*2	84	-0.64	-0.68	-0.49	-0.13	-0.02	-0.15	0.99	1.29	1.54
MG	84	-2.30	-2.46	-2.11	-11.49	-10.76	-10.58	26.30	24.31	23.80
MGSV	84	-1.77	-1.93	-1.87	-4.16	-4.08	-4.17	7.04	6.86	7.04
PMGS	84	-2.71	-2.42	-2.46	-2.36	-2.97	-3.51	3.78	5.07	6.20
PXGS	84	-2.30	-2.27	-1.95	-2.86	-3.75	-4.48	5.52	7.39	8.93
RD	84	-2.82	-2.31	-2.82	-6.06	-7.29	-8.24	12.59	15.39	17.53
RUM	84	-2.58	-2.16	-2.25	-14.40	-14.53	-14.64	37.10	37.49	37.81
WM	84	-0.85	-1.36	-1.38	-0.92	-0.94	-1.04	2.19	2.23	2.42
WPI	84	-1.04	-1.42	-1.21	0.30	0.06	-0.14	1.53	2.00	2.40
X	84	-2.40	-2.54	-2.12	-4.33	-4.74	-5.06	7.79	8.69	9.41
XG	84	-2.43	-2.74	-2.61	-4.26	-4.51	-4.68	5.93	6.48	6.86
XGSV	84	-2.02	-2.18	-2.19	-2.69	-3.01	-3.26	3.67	4.35	4.90
YCB	75	-1.79	-1.58	-2.21	-6.34	-7.14	-7.47	15.55	17.43	18.20
III	257	-2.34	-2.80	-2.99	-8.10	-8.68	-9.18	13.23	14.47	15.53
IPI	257	-1.21	-1.17	-1.28	-5.14	-3.73	-3.22	9.43	6.46	5.39
ISI	257	-1.53	-1.49	-1.59	-6.04	-4.53	-3.88	10.41	7.21	5.82
MOP	136	-2.69	-2.19	-1.92	-46.94	-42.01	-41.69	191.2	165.1	163.4
MOED	137	-3.98	-3.39	-3.33	-61.75	-59.54	-58.20	315.6	300.1	290.8
VCOD	137	-3.79	-2.70	-2.49	-62.66	-60.16	-60.65	327.7	309.1	312.8
BCP	256	-3.44	-3.07	-2.58	-58.03	-52.67	-50.15	172.7	153.9	145.0
RTI	257	-1.91	-1.95	-2.12	-9.22	-8.04	-7.86	20.79	18.24	17.85
WRTI	257	-1.55	-1.59	-1.72	-6.27	-5.64	-5.51	14.99	13.66	13.38

WTI	257	−1.67	−1.49	−1.53	−8.20	−7.20	−6.84	19.08	16.94	16.17
EPI	246	−1.27	−1.74	−1.98	−1.12	−1.41	−1.68	2.40	2.99	3.53
MPI	246	−1.75	−2.05	−2.14	−1.77	−2.14	−2.45	2.32	3.06	3.68
AW	256	−0.30	−0.22	−0.31	−3.92	−2.08	−1.22	9.13	5.29	3.50
M1V	258	−1.13	−1.19	−1.18	−2.22	−2.13	−2.09	4.36	4.18	4.10
MC	246	−1.99	−1.95	−2.14	−19.89	−15.43	−13.43	38.49	27.58	22.68
XC	246	−2.63	−2.66	−2.75	−10.09	−8.06	−6.97	15.57	11.10	8.69
LC	246	−2.82	−2.61	−2.83	−10.29	−8.61	−7.66	17.45	13.76	11.67
IL	246	−1.88	−1.83	−1.99	−18.79	−14.54	−12.83	35.59	25.29	21.14
RKO	89	−2.32	−2.28	−2.15	−2.00	−2.37	−2.70	1.89	2.67	3.35
RJA	89	−0.97	−1.35	−1.38	−1.40	−1.78	−2.05	4.50	5.29	5.83

Note: Asymptotic critical values for *ADF*, $\hat{Z}_\alpha$ and *HMS* at 5% significance level are −3.41, −21.8 and 43.41, respectively.

2.2. Results using model (1)

Data	T	*ADF2*	*ADF3*	*ADF4*	$\hat{Z}_\alpha(2)$	$\hat{Z}_\alpha(3)$	$\hat{Z}_\alpha(4)$	*HMS*(2)	*HMS*(3)	*HMS*(4)
E	84	−1.58	−1.66	−1.64	−1.59	−1.71	−1.81	0.93	1.17	1.39
RD	84	−2.44	−2.14	−2.41	−4.48	−5.16	−5.68	6.85	8.35	9.49
RUM	84	−1.48	−1.14	−1.13	−4.51	−4.41	−4.31	1.40	7.16	6.95
YCB	84	1.47	−1.30	−1.55	−5.28	−5.77	−5.97	9.61	10.74	11.19
RKO	89	−0.95	−1.17	−1.19	−0.15	−0.31	−0.45	0.18	1.10	1.38
RJA	89	−1.10	−1.32	−1.51	−1.52	−1.64	−1.73	1.45	1.70	1.88

Note: Asymptotic critical values for *ADF*, $\hat{Z}_\alpha$ and *HMS* at 5% significance level are −2.86, −14.1 and 27.69, respectively.

Appendix 3: 95% confidence interval

3.1. Demeaned and detrended

Data	AR(2)	AR(3)	AR(4)	AR(5)	AR(6)
C	1.430	1.377	1.255	1.194	1.231
	0.997	0.938	0.804	0.733	0.763
CG	0.977	0.988	1.134	1.103	1.094
	0.591	0.483	0.610	0.565	0.534
*CP*1	1.306	1.211	1.352	1.195	1.149
	0.864	0.763	0.892	0.724	0.668
*CP*2	1.170	1.218	1.092	1.156	1.158
	0.727	0.770	0.728	0.787	0.789
CPI	1.310	1.435	1.100	1.149	1.267
	0.872	1.020	0.669	1.016	0.848
E	1.367	1.443	1.193	1.262	1.186
	0.932	1.010	0.739	0.803	0.739
GDP	1.218	1.039	1.192	1.160	1.165
	0.765	0.604	0.755	0.718	0.718
GNP	1.296	1.106	1.207	1.181	1.191
	0.852	0.673	0.776	0.743	0.749
GNPA	0.903	0.886	0.781	0.988	1.009
	0.392	0.340	0.222	0.377	0.367
IF	1.137	1.274	1.067	1.217	1.241
	0.687	0.824	0.608	0.750	0.777
IFC	0.912	1.078	1.065	0.995	1.053
	0.429	0.569	0.543	0.457	0.506
IFM	1.007	1.436	0.817	1.143	1.430
	0.559	1.001	0.394	0.677	0.979
LE	1.003	1.071	1.295	1.183	1.183
	0.551	0.603	0.827	0.707	0.700
LEA	1.014	0.986	1.191	1.259	1.242
	0.572	0.535	0.716	0.782	0.762
M	1.111	1.346	0.906	1.120	1.199
	0.665	0.911	0.475	0.662	0.731
*M*2	1.364	1.303	1.219	1.485	1.247
	0.923	0.850	0.731	1.003	0.754
MG	1.077	1.321	0.884	1.097	1.183
	0.627	0.883	0.451	0.633	0.708
MGSV	1.263	1.492	0.942	1.162	1.154
	0.823	1.084	0.528	0.725	0.712
PMGS	1.418	1.205	0.917	1.204	1.011

	0.978	0.747	0.513	0.772	0.579
PXGS	1.267	1.169	0.899	1.009	1.371
	0.838	0.735	0.480	0.569	0.921
RD	1.303	0.954	1.346	1.308	1.190
	0.882	0.532	0.916	0.880	0.766
RUM	1.088	0.973	1.159	1.104	0.985
	0.636	0.516	0.683	0.620	0.492
WM	1.446	1.588	1.293	1.280	1.559
	1.012	1.171	0.820	0.802	1.086
WPI	1.392	1.397	1.149	1.226	1.317
	0.957	0.960	0.698	0.767	0.855
X	1.276	1.380	0.883	1.170	1.068
	0.842	0.956	0.463	0.718	0.612
XG	1.262	1.343	1.018	1.194	1.190
	0.825	0.908	0.577	0.737	0.729
XGSV	1.368	1.265	0.989	1.242	1.204
	0.934	0.822	0.546	0.781	0.741
YCB	1.079	1.074	1.412	1.138	1.264
	0.629	0.612	0.963	0.684	0.807
III	1.154	1.283	1.167	1.134	1.101
	0.908	1.041	0.921	0.890	0.857
IPI	1.068	1.137	1.176	1.217	1.102
	0.819	0.887	0.924	0.965	0.848
ISI	0.988	1.108	1.148	1.190	1.113
	0.739	0.856	0.893	0.936	0.858
MOP	0.803	0.814	0.963	1.011	0.958
	0.426	0.422	0.548	0.588	0.531
MOED	0.637	0.795	0.935	0.835	0.961
	0.259	0.370	0.481	0.371	0.472
VCOD	0.754	0.792	0.963	0.956	1.034
	0.367	0.392	0.536	0.520	0.555
BCP	0.809	0.889	0.924	1.058	1.045
	0.554	0.623	0.651	0.780	0.764
RTI	1.199	1.095	1.161	1.126	1.166
	0.953	0.848	0.914	0.878	0.918
WRTI	1.180	1.106	1.150	1.137	1.228
	0.935	0.859	0.903	0.890	0.984
WTI	1.143	1.024	1.097	1.151	1.178
	0.896	0.776	0.847	0.901	0.929
EPI	1.312	1.395	1.267	1.292	1.134
	1.065	1.153	1.017	1.043	0.881
MPI	1.204	1.298	1.238	1.176	1.264

	0.953	1.049	0.984	0.919	1.008
AW	0.781	1.036	1.185	1.213	1.142
	0.546	0.786	0.935	0.963	0.891
M1V	1.143	1.168	1.162	1.194	1.087
	0.896	0.919	0.909	0.938	0.829
MC	0.837	1.097	1.127	1.061	1.008
	0.595	0.844	0.874	0.809	0.755
XC	0.888	1.072	1.080	1.171	1.229
	0.636	0.812	0.819	0.910	0.968
LC	0.981	0.948	1.140	1.097	1.220
	0.729	0.694	0.883	0.838	0.964
IL	0.864	1.137	1.045	1.146	1.123
	0.615	0.879	0.787	0.882	0.858
RKO	1.215	1.365	1.234	1.443	1.100
	0.796	0.949	0.808	1.029	0.679
RJA	1.177	1.449	1.233	1.230	1.177
	0.755	1.031	0.799	0.791	0.745

3.2. Demeaned

Data	AR(2)	AR(3)	AR(4)	AR(5)	AR(6)
E	1.367	1.426	1.161	1.232	1.160
	0.934	0.990	0.701	0.772	0.711
RD	0.313	0.960	1.359	1.318	1.198
	0.886	0.535	0.924	0.881	0.761
RUM	1.173	1,057	1.255	1.201	1,076
	0.728	0.611	0.196	0.734	0.604
YCB	1.088	1.086	1.432	1.149	1.281
	0.634	0.625	0.980	0.691	0.819
RKO	1.204	1.362	1.228	1.434	1.088
	0.775	0.934	0.795	1.008	0.663
RJA	1.188	1.460	1.238	1.237	1.191
	0.766	1.046	0.805	0.800	0.762

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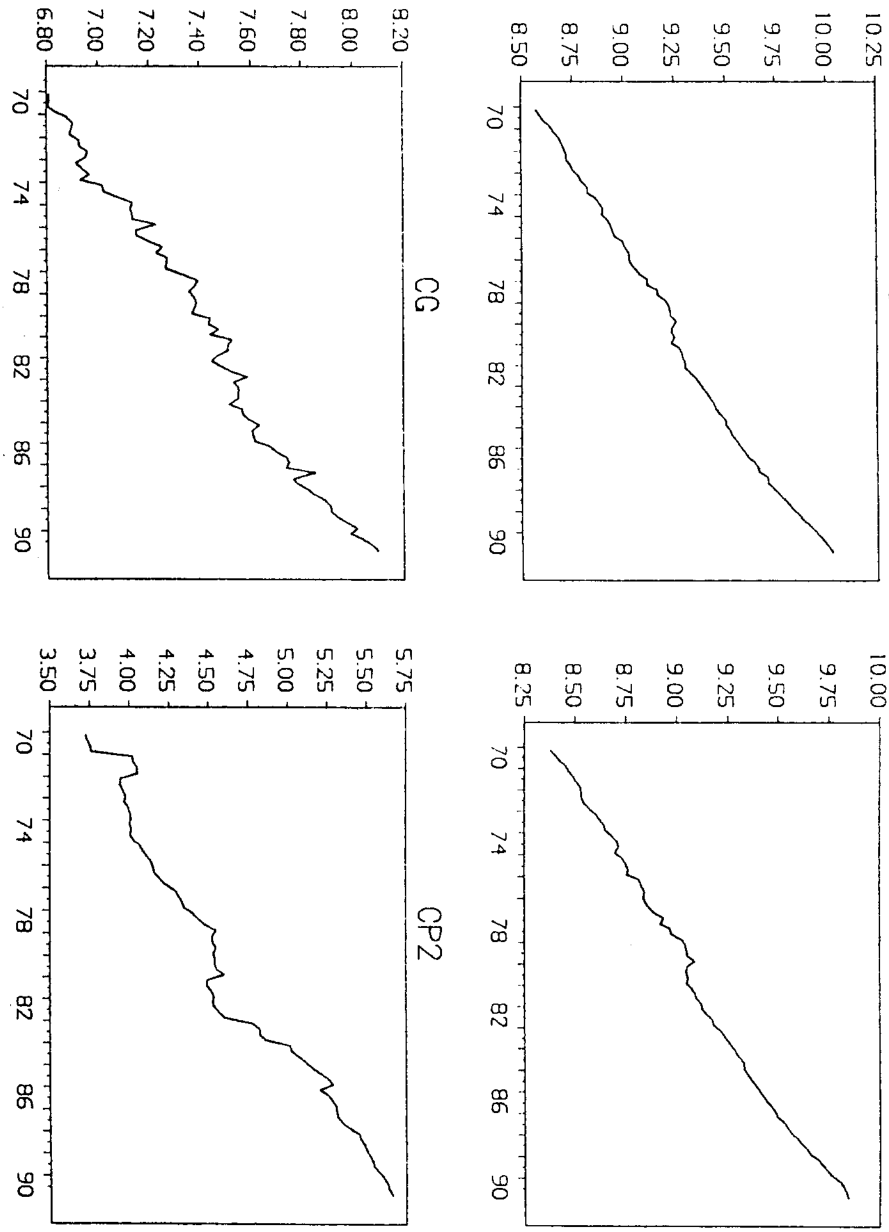
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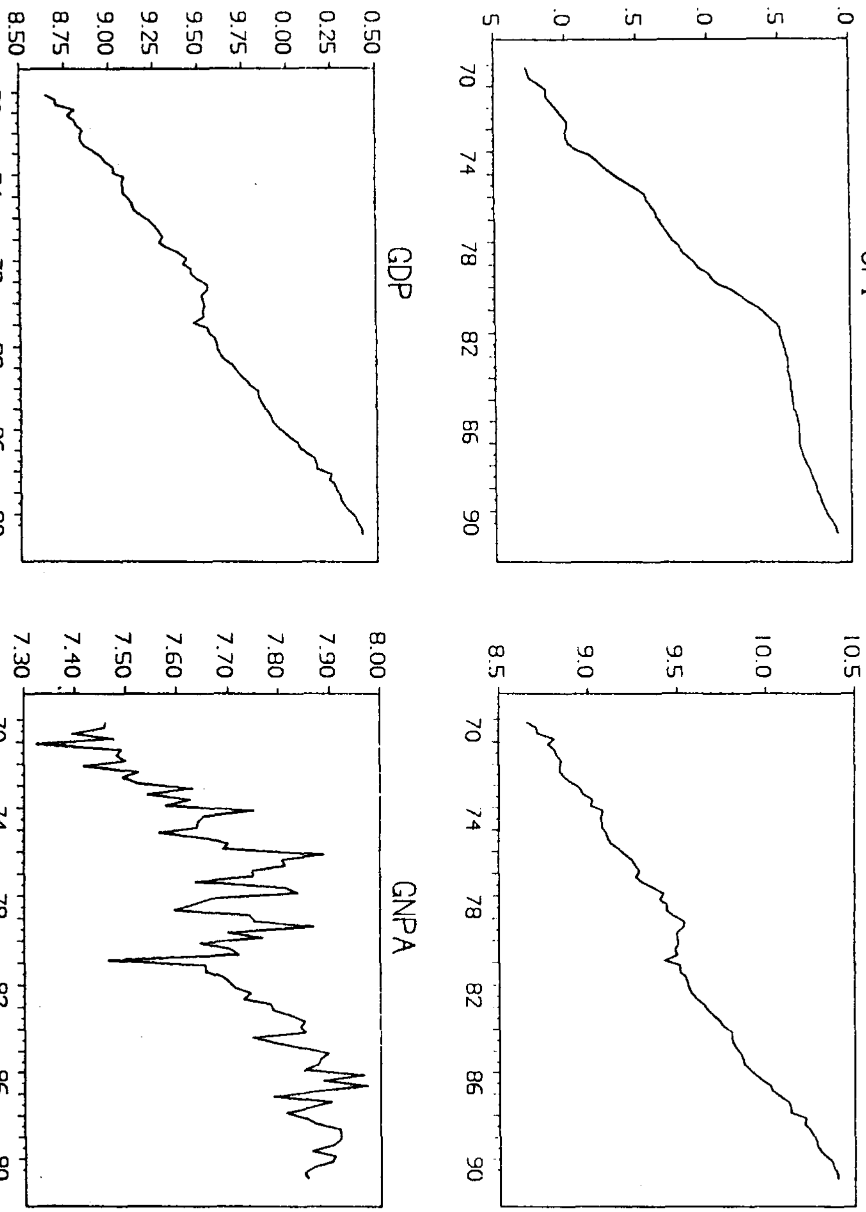
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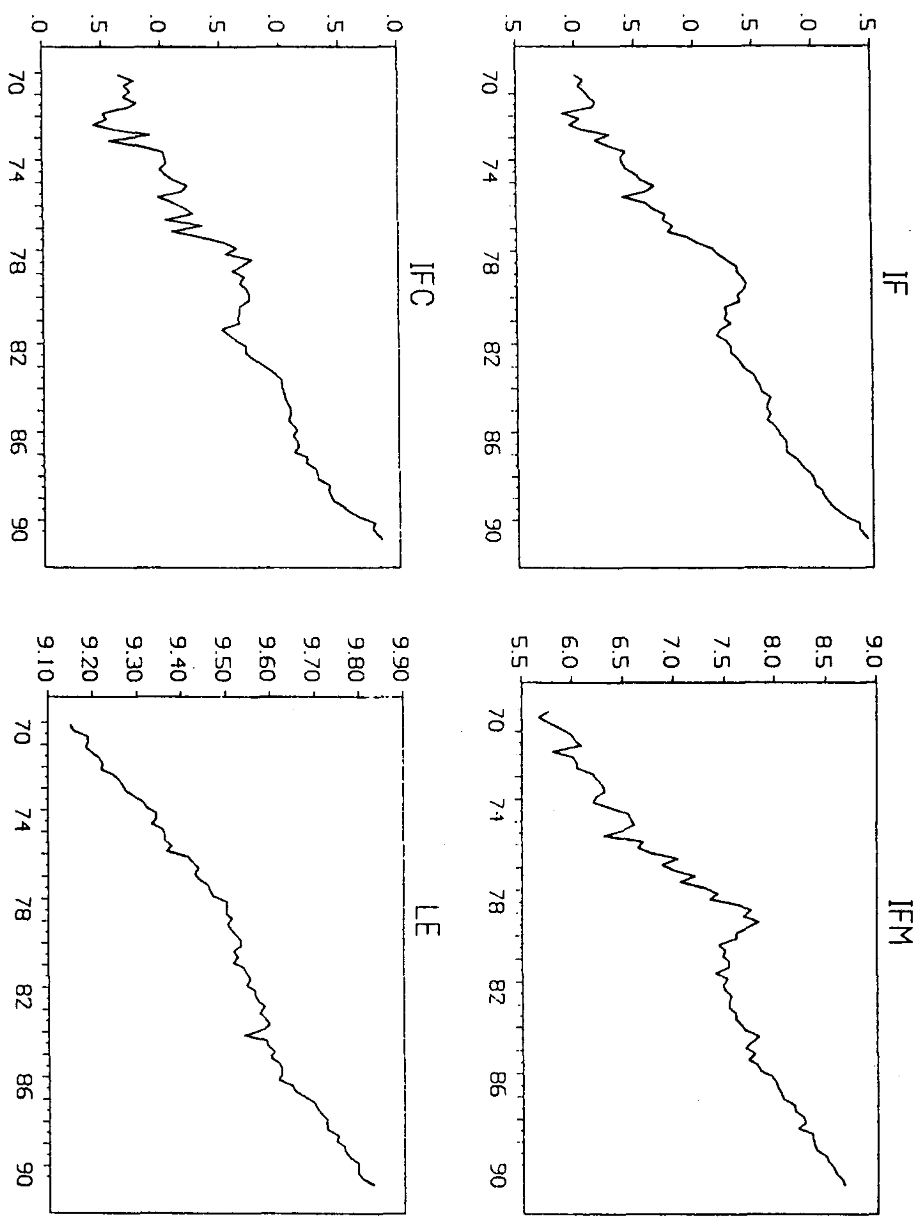
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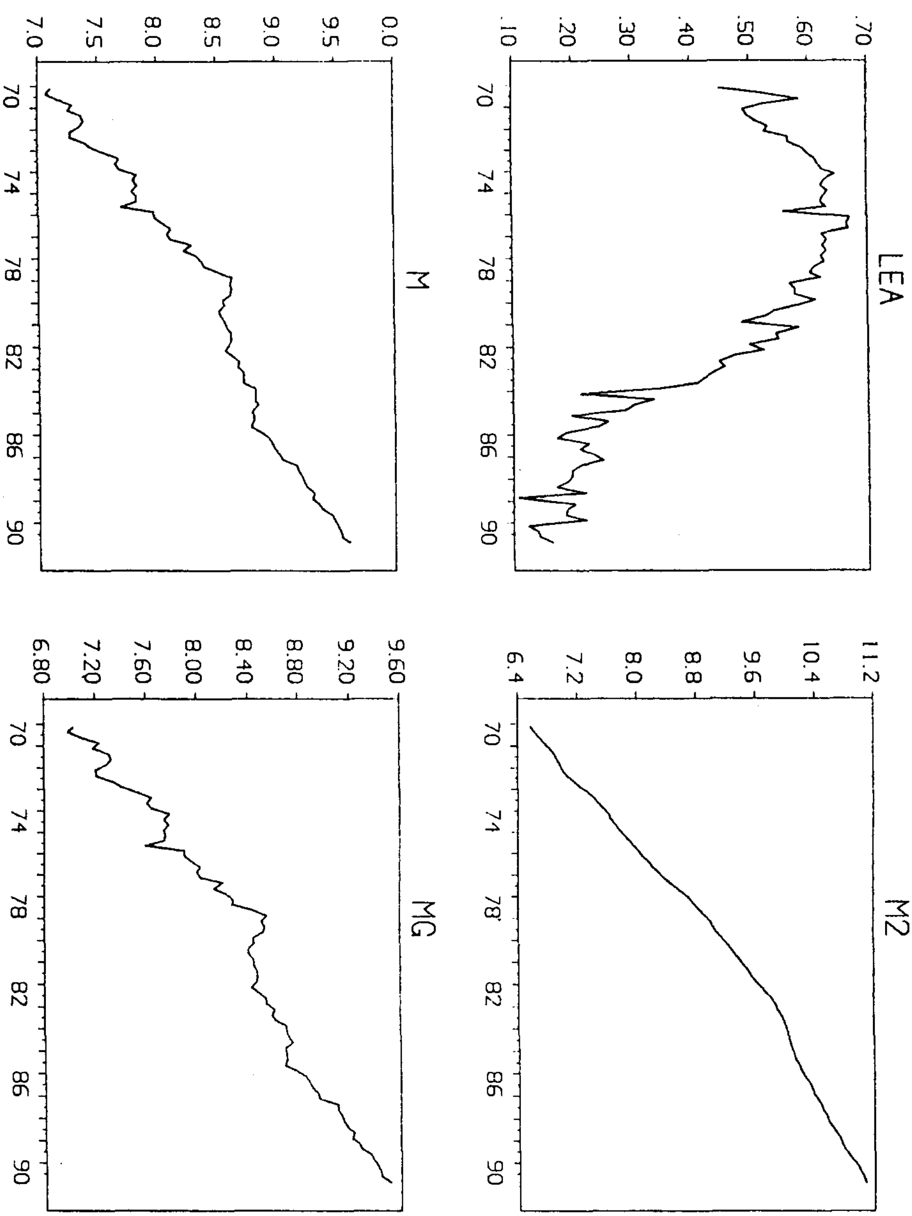
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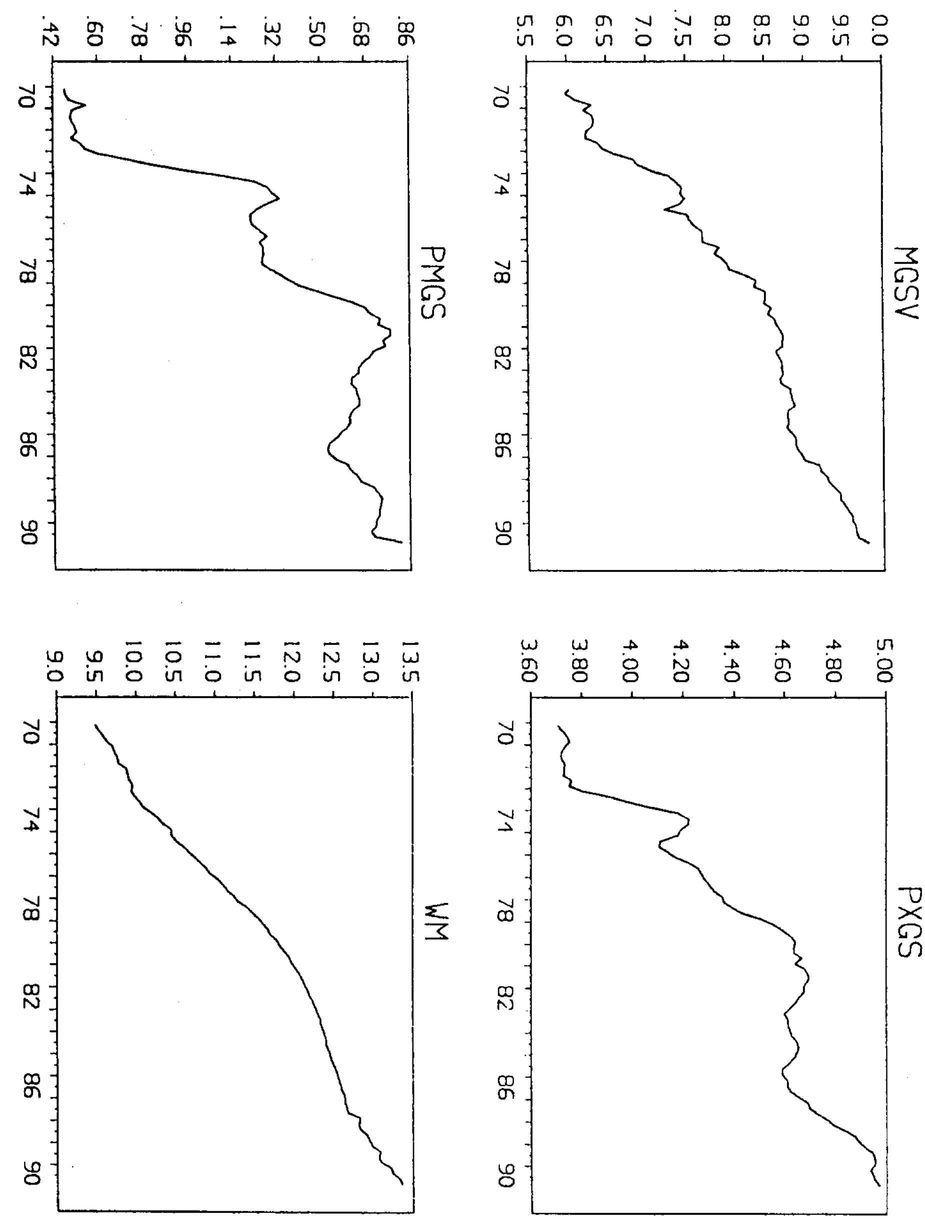
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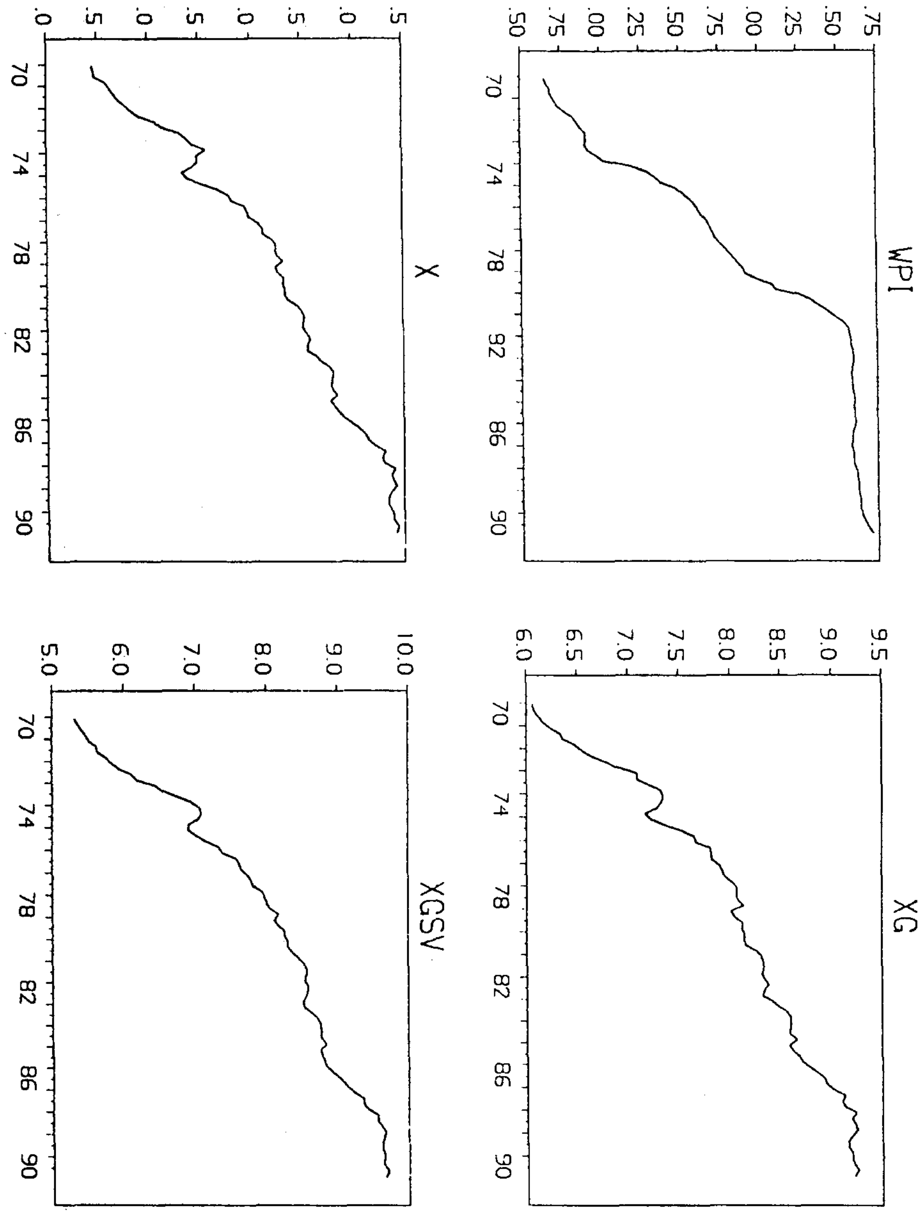
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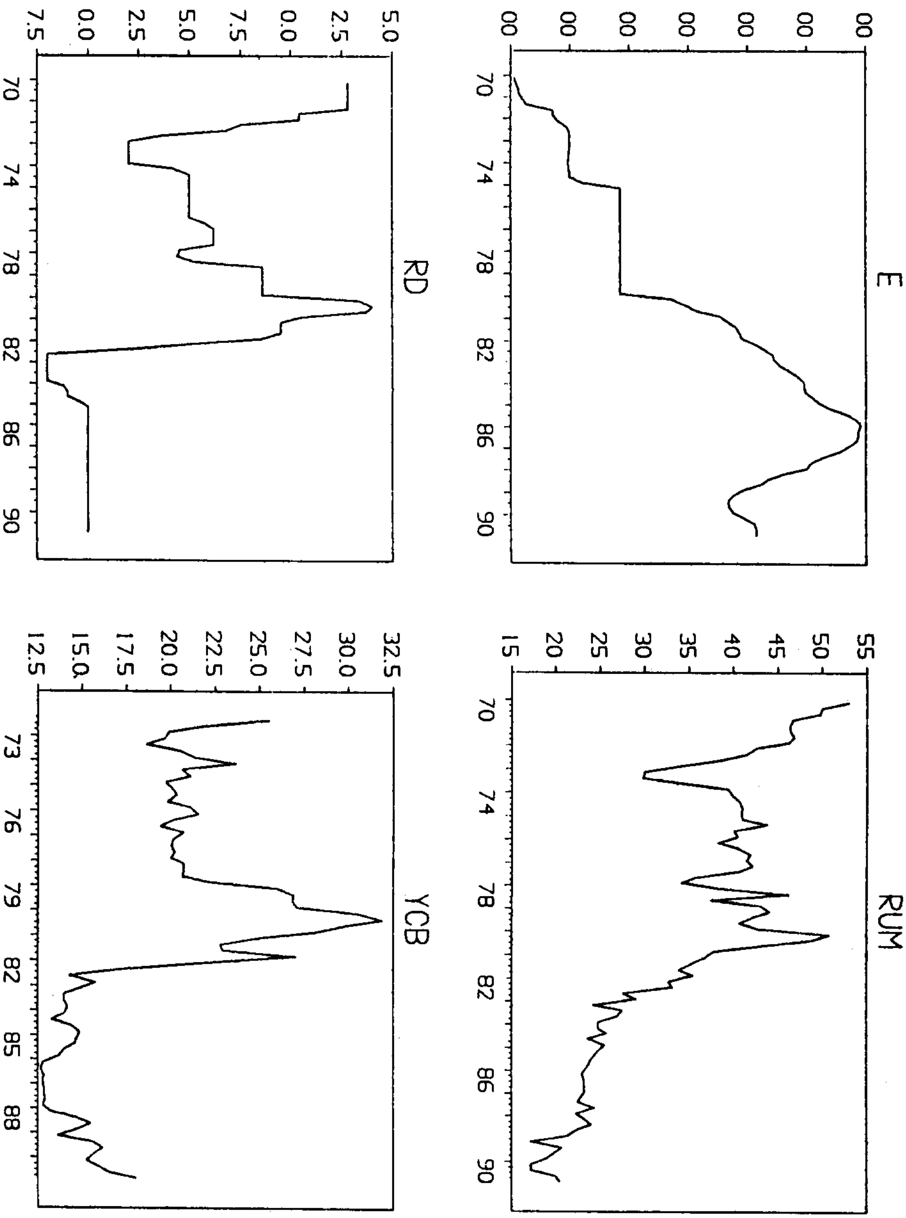
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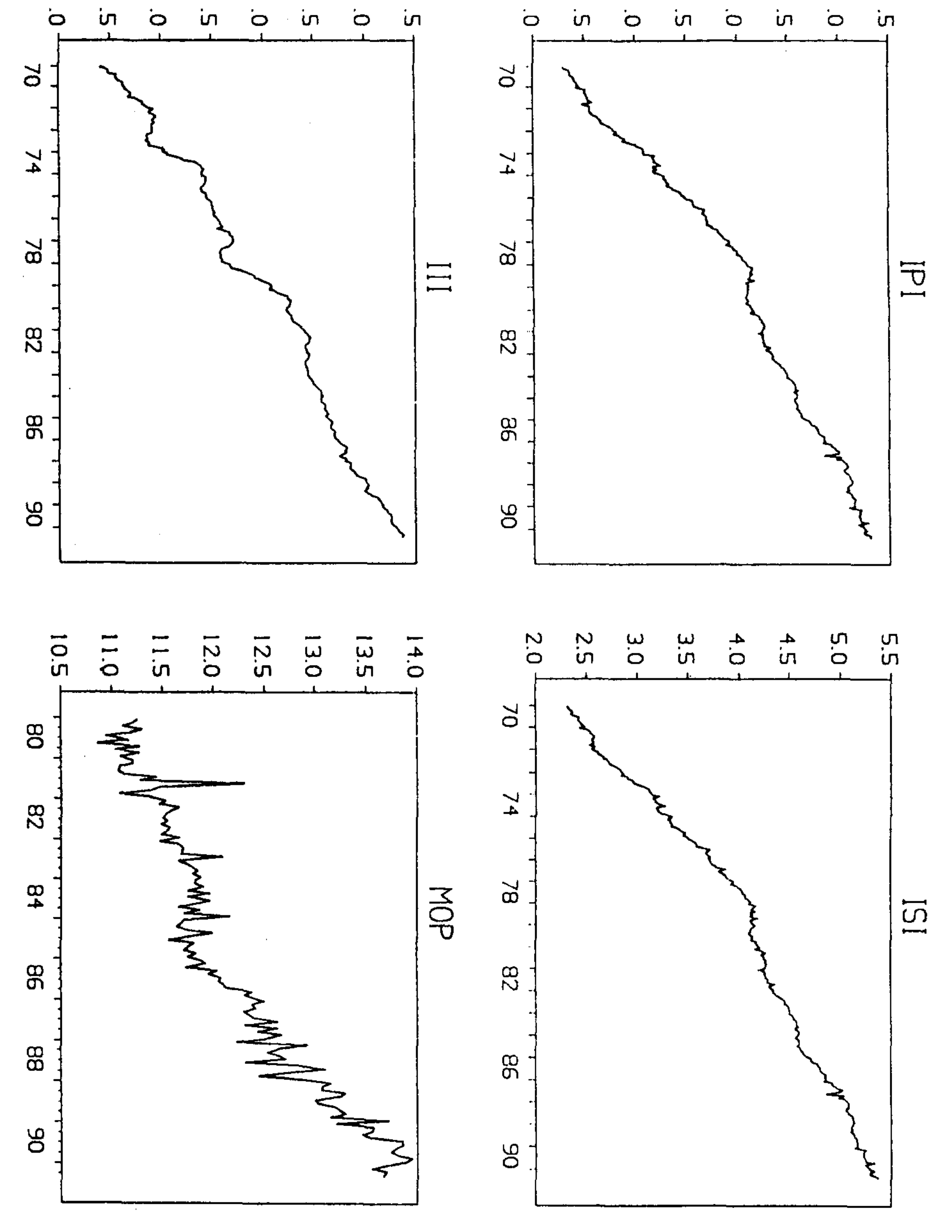

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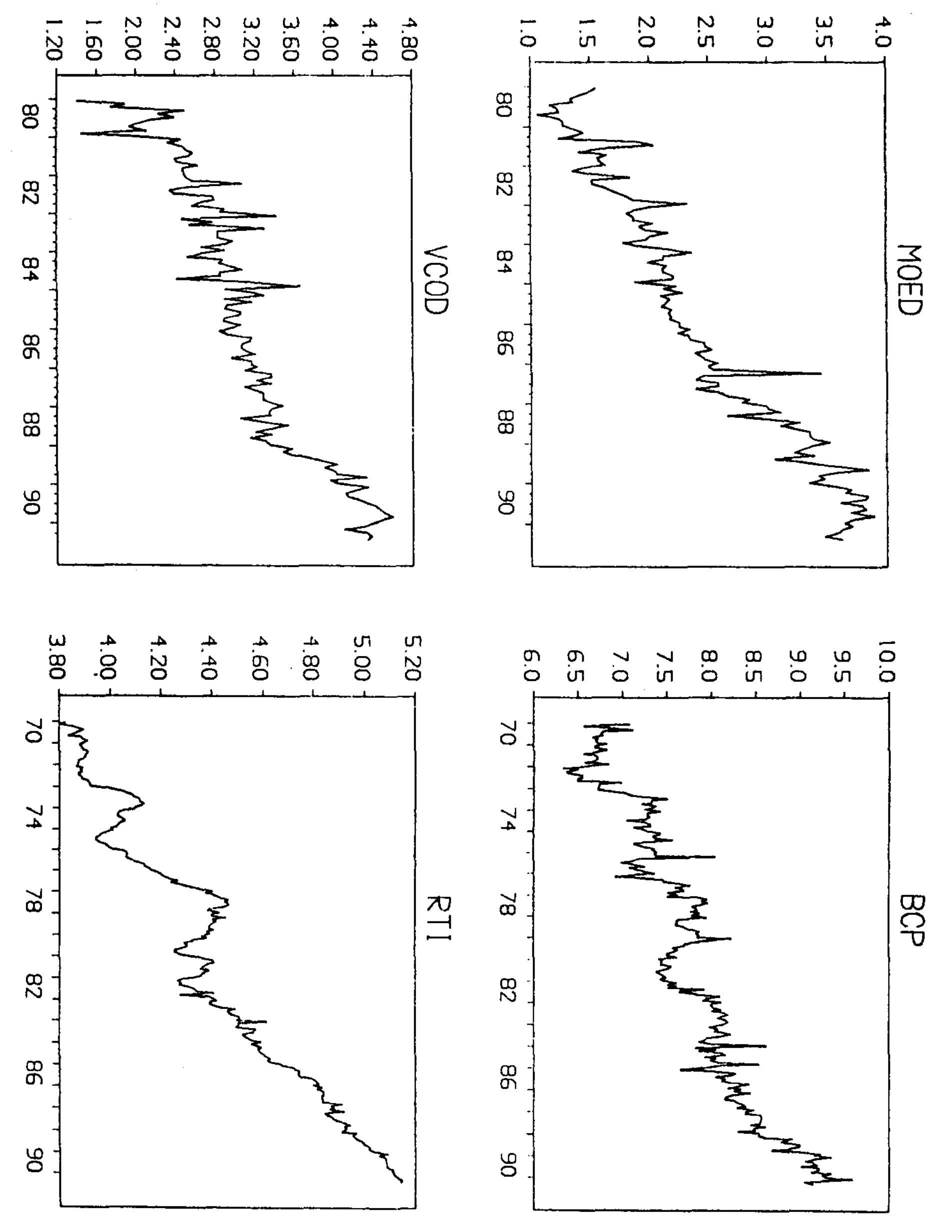
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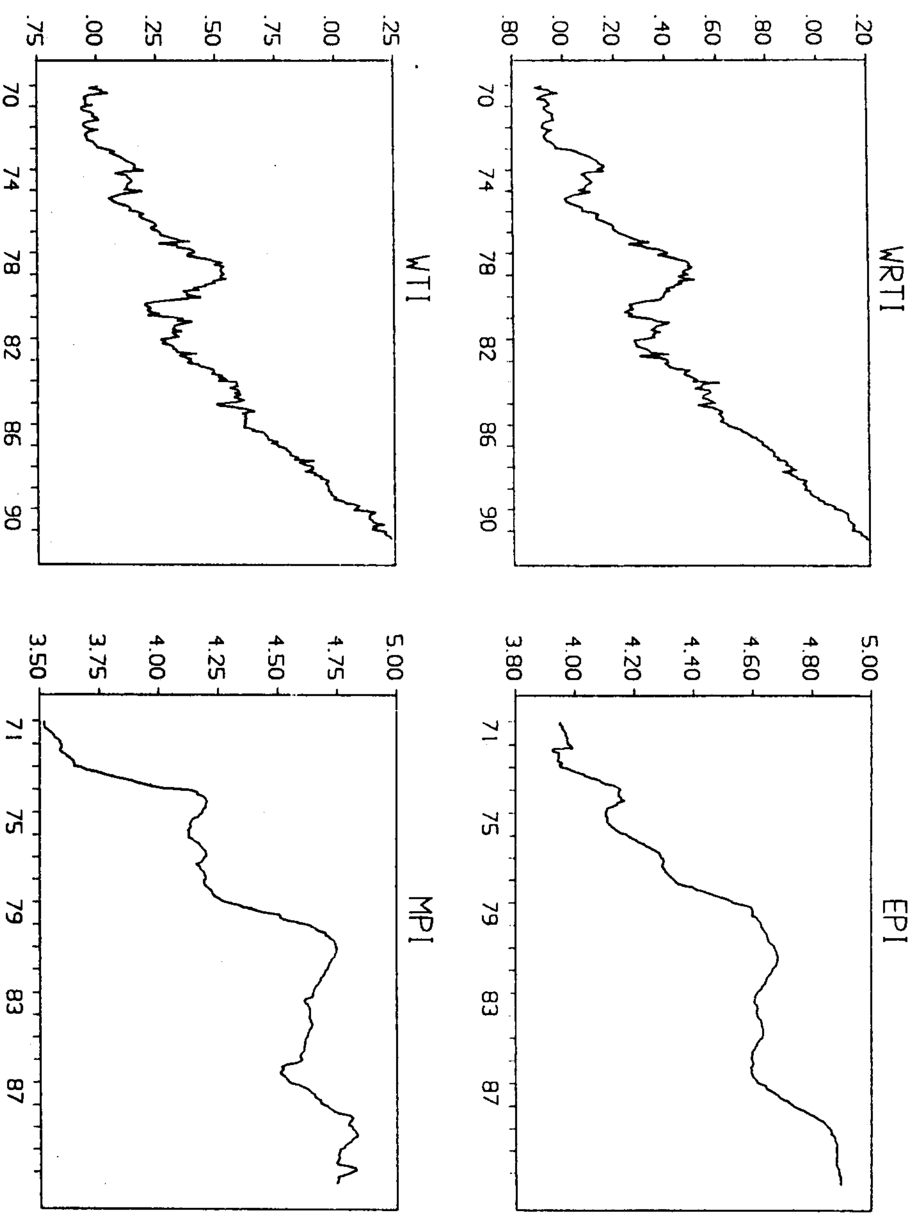
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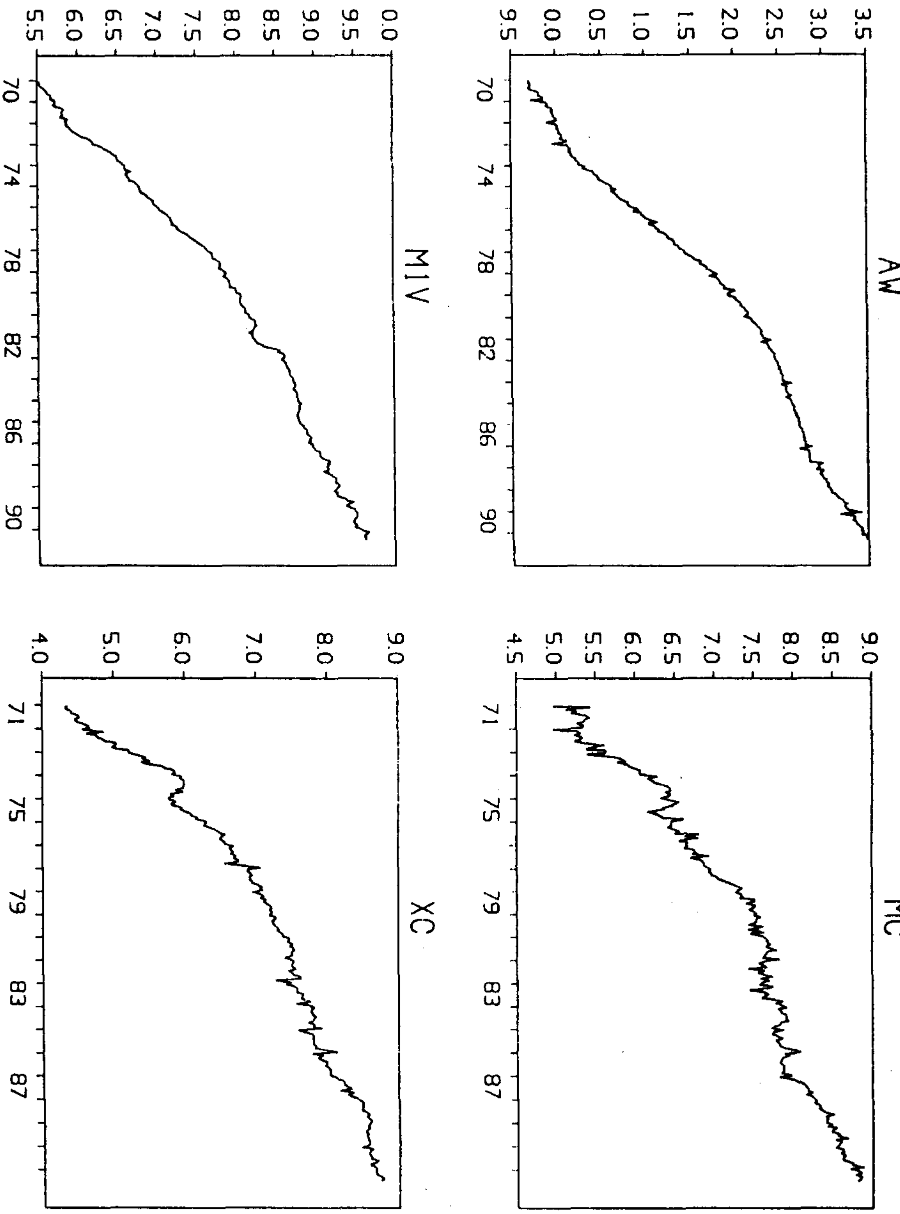
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M1V
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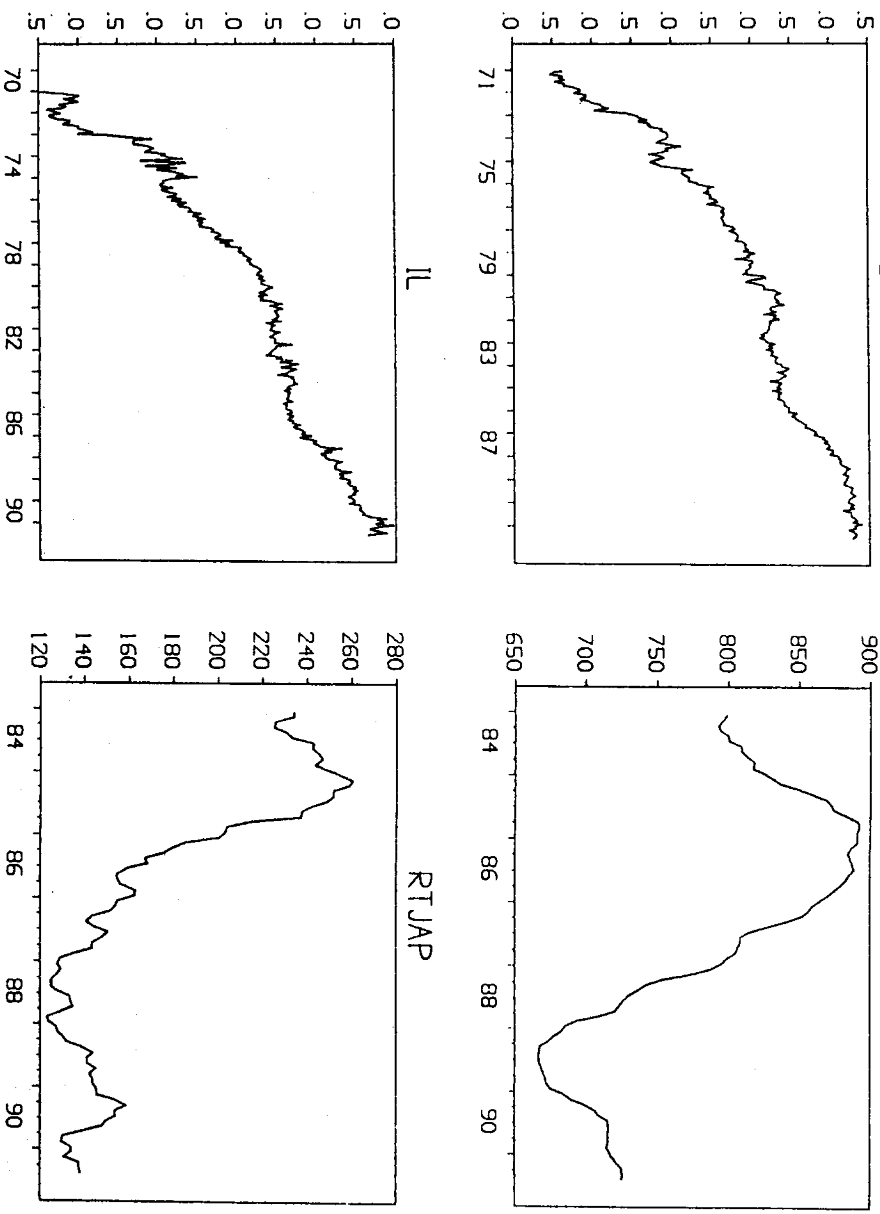
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RTJAP
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