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UNIT ROOTS IN THE YUGOSLAV MACROECONOMIC TIME SERIES

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ABSTRACT

The paper evaluates the nature of the nonstationarity in some Yugoslav macroeconomic time series. The application of most-commonly used tests for the discrimination between trend-stationary and difference-stationary class of models show that of models shows that most of the series considered contain a unit-root with a drift. The series are also tested for structural break. It has emerged only with respect of inflation rate. Thus, the use of ordinary unit-root tests shows that inflation rate has a unit root. However, in order to take care of a structural break, different procedure is employed, which brings the conclusion that inflation rate is trend-stationary process with structural change in its level.

INTRODUCTION

It is well-known that most macroeconomic time-series exibit a tendency to grow over time (i. e. they are nonstationary), which can be represented by two diferent class of models: trend-stationary or difference (integrated) stationary.[1]

If time series is difference-stationary, then its behaviour is described by the existence of unit roots. Number of unit roots is equivalent to the number of integration routines needed to achieve stationary representation of the series.[2]

The issue of trend-stationarity versus difference-stationarity is important in the theory of the business cycle. If a macroeconomic time series is trend-stationary, then short-term shocks e.g. due to the government policy, have only a temporary impact on the long-run evolution of the series, which is consistent with the traditional theories of the business cycle. But, if the time series is difference-stationary, then

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[1] For details see: Nelson and Plosser (1982).

[2] Statistical inference of the existence of unit roots in time series is described in Dickey, Bell, Miller (1986).

short-term shocks have influence on the level of the series that persists through time.[3]

Discrimination between trend-stationary and difference-stationary representation is also crucial for the theory of cointegration. The concept of cointegration is based on the assumption of the existence of unit roots in analyzed series. Two or more difference-stationary series are cointegrated, if their linear combination is stationary.[4] The growing interest of economists for the concept of cointegration lays in its ability to describe long-run relations among levels of the series. Implementing the theory of cointegration one can find an equilibrium solution.

If series is difference-stationary, then asymptotic properties of least- squares estimator of the parameter differ from those obtained by the estimation of trend-stationary series. The well-known result from statistical theory is that autoregressive estimate has non-standard limiting distribution and possesses the feature of "super-consistency", meaning convergency in probability to the true value of parameter at the faster rate than usual.[5] This is the reason why detecting the presence of unit roots needs special type of statistical testes.

The purpose of this paper is to evaluate the nature of the non-stationarity in some Yugoslav macroeconomic time series. The short survey of commonly used tests for detecting the existence of unit roots is given in part one of this paper. In part two, described methodology is applied in order to test the presence of unit roots in the Yugoslav macroeconomic time series. In part three we attempt to analyze the nature of inflation rate related to the change in its level, due to the structural break that has occured during the period of estimation. Part four concludes.

1. UNIT-ROOT TESTS

We consider stohastic process $\{x_t\}$ generated by the model:

$$x_t = a + bt + J_t \tag{1}$$

Multiplying (1) by $(1 - \Phi L)$ gives:
where: $x_0 = 0$, $J_t = (1 - \Phi L)^{-1} e_t$, e_t : iid N $(0, \sigma^2)$, L is the lag operator.

$$x_t = \alpha + \beta t + \Phi x_{t-1} + e_t \tag{2}$$

and: $\alpha = \alpha(1 - \Phi) + \Phi b, \beta = b(1 - \Phi)$.

Trend-stationary class will be appropriate for the representation of the process x_t in the case: $\Phi < 1$, which implies the stationarity of process J_t.

[3] There have been several attempts to measure shock persistence. See Campbel and Mankiw (1987).

[4] Engle and Granger (1987).

[5] Proofs can be found at different places, depending on various maintained assumptions. See Phillips (1987) for weak ones.

In the case $\Phi = 1$, we have $J_t = J_{t-1} + e_t$, meaning J_t is process with unit root, known as random walk. The process $\{x_t\}$ will be defined as random walk with drift if $x_t = b + x_{t-1} + e_t$.

Obviously, the value of parameter Φ determines the correct representation of process x_t. Hence we are interested in testing the following hypotheses:

$$\begin{cases} H_0 : \Phi = 1 \text{ process is difference-stationary} \\ H_1 : \Phi < 1 \text{ process is trend-stationary} \end{cases} \tag{3}$$

The most-commonly used Dickey-Fuller test statistics (DF) are·

$$r_t = T\,(\hat{\Phi} - 1)$$
$$r_t = T\,(\hat{\Phi} - 1)\,/\,s\,(\hat{\Phi})$$

($\hat{\Phi}$ is a least squares estimator of parameter Φ obtained from sample of size T and s ($\hat{\Phi}$) is the standard error of $\hat{\Phi}$).[6]

These statistics have non-standard limiting distribution, skewed to the left, comparing with t-distribution. The critical values (for different size of a sample) are tabulated in Fuller (1976).

The hypotheses of interest are actually joint hypotheses. The hypothesis H_o can be stated as: $H_o : (\alpha, \beta, \Phi) = (b, 0, 1)$ and can be tested by the appropriate version of F-test introduced by Dickey and Fuller (1981).

Sometimes it is important to check if unit-root process has a drift. Then, we are testing the hypothesis: $H_o : (\alpha, \beta, \Phi) = (0, 0, 1)$ with the version of F-test that is available in Dickey and Fuller (1981), along with the critical values.[7]

The Dickey-Fuller test statistics are dramatically affected by serial correlation.[8] In order to cope with this problem, Said and Dickey (1984) proposed the following modification of the model (2):

$$dx_t = \alpha + \beta t + (\Phi - 1)\,x_{t-1} + \sum_{k=1}^{T} dx_{t-k} + e_t \tag{4}$$

where t-statistic for the coefficient on x_{t-1} becomes augmented Dickey-Fuller test statistic (ADF). For large samples the limiting distribution of ADF test is equivalent to the limiting distribution of DF test. New regressors dx_{t-k} are added to cope with the problem of autocorrelation. There are various ways to choose the number of lags.[9]

[6] Rearranging (2) as $dx_t = \alpha + \beta t + (\Phi - 1)\, x_{t-1} + e_t\,(dx_t = x_t - x_{t-1})$, r-statistic becomes usual t-statistic of the coefficient $(\Phi - 1)$.

[7] According to Stock and Watson (1989), the presence of drift in nonstationary process can be tested by ordinary t-statistic for a regression of dx_t on constant.

[8] See Schwert (1989), for example.

[9] See Pagan and Wichern (1989).

Philips and Perron (1988) have developed test-statistics for the cases when disturbances are heteroscedastic and autocorrelated. These statistics known as Z or PP statistics, have the following form:

$$z(\Phi_t) = T(\Phi - 1) - (T^6 / 24\, Dx)(s^2_{Tl} - s_e^2)$$

$$z(\tau_t) = (s_e / s_{Tl})\tau_t - (T^3 / 4\,(3Dx)^{1/2} s_{Tl})(s^2_{Tl} - s_e^2)$$

where: $s_e^2 = T^{-1} \sum_{t=2}^{T} e_t^2$, $s^2_{Tl} = s_e^2 + 2T^{-1} \sum_{i=1}^{l} w_{il} \sum_{t=i+1}^{T} e_t e_{t-i}$, $w_{il} = 1 - i/(1+i)$, (l is the cutoff point of weighted autocovariances)[10], $Dx = \det(X'X)$, X is the vector of all regressors.

For the case e_t : iidN $(0, \sigma^2)$, z-test is the usual DF test. However, it is shown (Phillips and Perron (1988)) that limiting distribution of z-test is equivalent to the limiting distribution of DF test. So, critical values tabulated in Fuller (1976) are also valid for z-test statistics. Analogous transformations of F-test defined by Dickey and Fuller (1981) are available in Perron (1990).

Stock and Watson (1986) developed a method to examine the number of unit roots in vector stohastic processes. This procedure applied on univariate time series becomes a test for detecting the presence of unit roots (q-test). It is consisted of two steps. First, one de-trends original series by regressing it on constant and (or) trend. Then, the value of r_t statistic of de-trended series is calculated and compared with critical values tabulated in Stock and Watson (1986).

Perron (1989) showed that standard tests of the unit root hypothesis against trend-stationarity alternative cannot reject the unit-root hypothesis if the series is stationary containing a structural break. In order to distinguish between these two classes when structural break occurs, Perron (1989) derived a test that can take care of an exogeneous change in the level of the series. In this framework, under the null hypothesis, the series x_t is the unit-root process with the change in its structure that occurs at a time T_B. This hypothesis can be parameterized as follow:

$$x_t = b + \delta d_B + x_{t-1} + w_t \qquad (5)$$

where $d_B = 1$ if $t = T_B + 1$ and 0 otherwise.

Under the alternative hypothesis, trend-stationarity with the change in the intercept of the trend-function is allowed. Process of this type is modeled as:

$$x_t = b_1 + vt + (b_2 - b_1)\, d_t + w_t \qquad (6)$$

where $d_t = 1$ if $t > T_B$ and 0 otherwise.

Model (5) can be tested against model (6) using t-statistic for testing $\Phi_B = 1$ in the following regression estimated by ordinary least squares:

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10 Details can be found in Phillips (1978) and Perron (1988).

$$\hat{x}_t = \hat{b}^B + \hat{v}^B t + \hat{\delta}^B d_B + \hat{\varepsilon}^B d_t + \hat{\Phi}^B x_{t-1} + \sum_{k=1}^{T} \hat{\gamma}^B dx_{t-k} \quad (7)$$

This statistic has non standard distribution and depends on the parameter λ defined as $\lambda = \frac{T_B}{T}$. Appropriate critical values are tabulated in Perron (1989). When there is no trend, values presented in Perron (1990a) are used.

Using this framework Perron (1989) reexamined the nature of 13 series analyzed by Nelson and Plosser (1982) and get somewhat different results: out of 13 series, only 3 have unit roots. The rest of them are characterized by trend-function with a major change in the level occuring after the 1929 Great Crash.

2. EMPIRICAL EVIDENCE

The tests described will be now applied on a set of the Yugoslav monthly and quarterly macroeconomic time series.

Set of ten monthly macroeconomic time series is considered: money stock M1 (m1), high powered money (h), retail price index (p), wage rate (w), exchange rate (ex), consumer price index (pc), industrial price index (p1), industrial employment (em), industrial production index (qi) and non-agricultural production index (qn).

The logarithms of the series are taken in order to avoid their heteroscedasticy. We also consider three additional serdies: inflation rate ($dp_t = p_t - p_{t-1}$), real money stock ($mlr = ml - p$) and real high powered money ($hr = h - p$).

The sample period is: January 1980 — November 1989, due to policy regime change that took place in mid December 1989.

The following quarterly series are analyzed: personal consumption, public and government consumption, export, import and GNP. The data are deflated and a period considered is: first quarter 1966 — second quarter 1989.

We apply Dickey-Fuller test, augmented Dickey-Fuller test, Phillips- Perron test and Stock-Watson test to find out whether these series are properly represented by trend-stationary or difference-stationary class of models. While testing, Perron (1988) is followed.

Let us start with monthly macroeconomic time series and estimate the autoregressive model (2):

$$\hat{x}_t = \hat{\alpha} + \hat{\beta} t + \hat{\Phi} x_{t-1} \quad (8)$$

The estimated model (8) is used to test the hypotheses (3) by calculating various test-statistics. Additional regressors dx_{t-k} are also included and the results are presented in table 1.

All tests reject hypothesis H_0, that the unit roots is present, for the following series: industrial production index and non-agricultural production index. However, all other series have unit root, i. e. H_0 is accepted.

The testing procedure is repeated for the first (and second) differences of the series for which we couldn't reject H_0, in order to determine the number of unit roots. Hence we consider regression model:

$$dx_t = \alpha_1 + \beta_1 t + \Phi_1 d^2 x_{t-1} \tag{9}$$

where d^2x_t denotes the second differences of x_t. The values obtained of the teststatistics are tabulated in table 2.

The existence of a unit root in the difference of the series implies the existence of two unit roots in the level of the series. If the first difference of the series is trend-stationary, then the original series contain only one unit root.

It follows, from table 2, that one unit root have: money stock M1, high powered money, wage rate, exchange rate, industrial employment, inflation rate, real money stock and real high powered money. Two unit roots have: retail price index, consumer price index and industrial price index.

As Perron (1988) proved, regression model (2) is adequate for the discrimination between trend-stationary and difference-stationary representation, only if original series with unit roots has a drift. To ascertain the existence of drift, we are testing the hypothesis $H_0 : (\alpha, \beta, \Phi) = (0, 0, 1)$. The appropriate version of F-test, along with Stock-Watson test (SW) are used. The results reported in table 3 show that following series have a drift: money stock M1, high powered money, wage rate, exchange rate, industrial employment, real money stock and real high powered money. The series without drift are: inflation rates for all three price indices: retail, consumer and industrial products.

When analyzed series doesn't have a drift, the correct regression model is:[11]

$$x_t^* = \alpha^* + \Phi^* x_{t-1} \tag{10}$$

Test-statistics based on regression model (10) for the series without drift (presented in table 4) confirm previous conclusion, i. e. all inflation rates contain two unit roots.[12]

Presented analyses brought out some contradictory results. It is obtained that money stock M1 has one unit root with a drift and retail price index two unit roots. On the other hand, if we take linear combination of two series each with different number of unit roots, then the resulting combination will have the number of unit roots equal to the highest one of individual series.[13]

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[11] Theoretical reasons are stated in Perron (1988).

[12] Test-statistics defined on model (10) have different asymptotic propterties than those obtained from model (8). We denote them: $\tau\mu$, $z(\tau\mu)$. Appropriate critical values are available in Fuller (1976).

[13] This is the fundamental result of the theory of co-integration (Engle and Granger (1987)).

This implies that linear combination between m1 and p will have two unit roots. This should also be valid for the linear combination (m1 — p), which represents series m1r, as previously defined. However, the application of unit root tests shows that series m1r has only one unit root. The same conclusion can be reported for the series hr. The meaning of this finding remains open. According to Perron (1988). who has found similar type of contradictory result in his empirical research, this problem calls for a deeper theoretical work.

Using the regression model (8) to investigate the nature of chosen quarterly macroeconomic time series, we reach the conclusion that all analyzed quarterly series are trend-stationary (table 5).

3. STRUCTURAL BREAK IN INFLATION RATE

Visual inspection of considered series implies that inflation rate might be stationary process for the period 1980,1—1988,6. After the data 1988,6 inflation exhibits a major change in its mean due to the start of hyperinflation. One can suspect that inflation rate is well described as stationary process with the change in its level that occured after the data 1988,6. In order to find out the correct answer, testing procedure defined in Perron (1989, 1990a) is applied.

The regression model (7) is run, where dummy variables are introduced in the following way: $d_t = 1$ for $t > 88,6$; 0 otherwise $d_B = 1$ for $t = 88,7$; otherwise. The following estimate is found:

$$\underset{(2.55)}{d^2p = 0.01} + \underset{(4.91)}{0.06d_t} - \underset{(-2.37)}{0.08d_B} - \underset{(-3.35)}{0.23dp_{-1}}$$

where t-ratios are in brackets and d^2p_{-1} is added. The statistic obtained is —3.35, while critical value at 5% level is equal to —3.10 for $\lambda = 0.1$. One can easily reject the null hypothesis (5) and conclude that inflation rate is stationary process with the structural break.

Under the alternative hypothesis all coefficients have t-statistics with asymptotic normal distribution, that enables us to determine their significance. This is the reason we reported results where trend term is omitted, since it was not significant.

Identical conclusion is drawn from the following table for the inflation rates of consumer and industrial price indices.

Series	b^B	ε^B	δ^B	Φ^B	k	DW
dpc	0.01	0.07	—0.10	0.73	1	2.04
	(2.62)	(4.96)	(—2.92)	(—3.63)		
dp1	0.01	0.08	—0.05	0.66	2	1.84
	(3.21)	(5.50)	(—1.45)	(—4.01)		

Note: t-ratios are in brackets.

The same result is reached when sample interval is extended for the data form the period 1989,12 — 1990,11:

$$d^2p = \underset{(2.04)}{0.01} + \underset{(2.76)}{0.03\, d_t} - \underset{(-2.32)}{0.09\, d_B} - \underset{(-3.81)}{0.21\, dp_{-1}}$$

where included dummy variables d_t takes value 1 for the period 1988,6—1990,11. Here, t-statistic is —3.81 which permits rejection at the 1% level (critical values is equal to —3.80 for $\lambda = 0.2$).

In order to model policy regime change that took place in mid December 1989, new dummy variables are included: $d_{1t} = 1$ for $t > 89,12$; 0 otherwise and $d_{1B} = 1$ for $t = 90,1$; 0 otherwise. We obtained the following result:

$$d^2p = \underset{(2.44)}{0.01} + \underset{(3.49)}{0.05 d_t} - \underset{(-2.81)}{0.11\, d_B} - \underset{(-0.67)}{0.01\, d_{1t}} - \underset{(-0.35)}{0.02\, d_{1B}} - \underset{(-3.50)}{0.22 dp_{-1}}$$

Hypothesis (6), that inflation rate is stationary process with structural break, is confirmed at the 5%, but included dummy variables d_{1t} and d_{1B} are not significant. One may conclude that rational expectations, based on the new economic program, didn't play important role in the inflation process. The question whether structural break occured upon policy regime change remains open, because it calls for a deeper research, based on the use of the dummy variables that would take care of a period when antiinflation program actually started to perform.

4. CONCLUSIONS

The nature of nonstationarity of some Yugoslav macroeconomic time series is analyzed by the implementation of unit-roots tests that have attracted the attention of the most applied workers. These are Dickey-Fuller test, augmented Dickey-Fuller test, Phillips- Perron test and Stock-Watson test. Using them we have been aware of the need to carry out an adequate testing strategy. Depending on the existance of a drift in considered series, different variants of regression models and test-statistics are employed in order to find out the correct answer.

Following conclusions are reached, concerning stationarity of the series considered:

1. All analyzed quarterly series (period: 1966,1—1989,2) are trend-stationary (personal consumption, public and government consumption, export, import and GNP);

2. The nature of analyzed monthly series (period: 1980,1—1989,11) is, as follows:

a) trend-stationary series are: industrial production index and non-agricultural production index;

b) unit-root series with drift are: money stock M1, high powered money, wage rate, exchange rate, industrial employment, real money stock and real high powered money;

c) unit root series without drift is inflation rate;

d) series with two unit roots are: retail price index, consumer price index and industrial price index.

These findings are supplemented by the reexamination of the nature of inflation rates of all price indices, in order to take care of possible structural break. As emphasised in the literature, an exogeneous change in the level of the series might lead to incorrect conclusion using the ordinary unit-root tests. Carrying out different testing procedure based on the inclusion of dummy variables due to the explosion of inflation, one can conclude that analyzed inflation rates are stationary processes with the structural break. The issue of concern has arisen over the possibility that structural break occured upon policy regime change that took place in mid December 1989. However, presented analysis doesn't provide enough informations on this subject. Further researches are probably going to take care of it.

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The presence of unit roots in monthly series
(regression model 8)

T. 1.

Series	z (τ_i)		DF (τ_i)	ADF (τ_i)		q	
	k=1	k=4	k=0	k=1	k=4	k=1	k=4
money stock M1	7.43	7.87	7.67	5.72	3.79	6.29	9.32
high powered money	4.20	5.23	80.65	4.02	3.95	4.91	6.16
retail price index	15.77	12.97	17.89	6.98	3.66	8.47	10.07
inflation rate	—1.76	—1.87	—2.46	—0.28	1.76	—5.19	—16.27
consumer price index	14.06	—11.82	15.94	6.64	3.75	7.95	10.26
industrial price index	14.50	12.94	16.09	7.27	4.41	8.21	8.31
wage rate	10.91	10.15	9.14	8.61	3.66	8.26	9.21
exchange rate	8.61	9.33	8.17	7.19	4.89	9.28	9.28
industrial employment	—0.45	—0.30	—0.91	0.007	0.06	—0.68	—2.50
real high powered money	3.00	—2.93	—3.36	—2.59	—1.46	—20.64	—23.78
real money stock M1	—2.18	—1.90	—2.13	—2.13	—1.58	—14.14	—13.57
industrial production index	—9.03	—8.84	—9.10*	—8.51	—5.81	—102.00	—97.91
non-agricultural production index	—8.93	—8.78	—8.85*	—8.43	4.46	—99.63	—89.65

Note: (1) Critical values are listed in table 2.

(2) *denotes values of DF statistic when there is no autocorrelation. In this case DF statistic is the preferred test. In all other tables * has the same meaning.

The presence of unit roots in first (and second differences) of monthly series (regression model 9)

Series	$z(\tau_t)$		DF (τ_t)	ADF (τ_t)		q	
	k=1	k=4	k=0	k=1	k=4	k=1	k=4
dm1	—4.87	—4.71	—6.79*	—4.89	0.83	—65.88	—75.64
dh	—8.39	—7.66	—10.65*	—7.17	—1.96	—116.87	—117.76
d^2p	—17.70	—19.18	—16.68*	—11.97	—4.91	—162.02	—171.42
dpc	—2.69	—2.85	—3.15	—0.93	1.65	—11.05	—22.59
d^2pc	—17.17	—19.07	—16.67*	—11.96	—5.44	—161.07	—170.74
dp1	—2.38	—2.47	—2.99	—1.19	0,50	—11.05	—22.42
d^2 p1	—17.06	—19.44	—16.57*	—12.14	—6.38	—158.49	—168.98
dw	—7.17	—8.05	—7.44*	—3.19	2.16	—64.02	—186.96
dex	—6.54	—7.39	—6.78*	—3.40	—0.77	—64.81	—86.06
dem	—14.90	—15.11	—14.34*	9.37	—5.37	—151.69	—154.66
dm1 r	—10.51	—12.12	—10.62	—10.52	—4.92	—119.37	—119.98
dhr	—13.55	—16.26	—13.32	—10.50	—5.44	—139.49	—144.95

T. 2.

Critical values

Test	10%	5%	1%
$z(\tau_t)$, ADF	—3.12	—3.41	—3.96
q	—18.2	—21.7	—29.2

Source: Fuller (1976), Stock, Watson (1986).

The presence of drift in monthly series with unit — root

	F — test		SW — test	
	k=1	k=4	k=1	k=4
m1	25,73	4,67	—9.30	—3.92
h	25.83	9.78	—5.50	—5.07
dp	1.85	2.98	1.36	—1.80
dpc	0.18	3.80	1.67	—0.87
dp1	1.75	2.52	1.62	—0.03
w	45.04	5.35	—10.04	3.30
ex	33.78	9.85	—5.16	—2.85
em	9.68	5.50	1.62	1.90
m1 r	5.14	4.48	—1.76	—2.55
hr	4.33	4.11	—0.98	—2.50

Critical values T. 3.

Test	10%	5%	1%
F	4.03	4.68	6.09
SW	1.66	1.98	2.62

Source: Dickey, Fuller (1981).

The presence of unit roots in series without drift (regression model 10)

Series	$z(\tau_\mu)$		$DF(\tau_\mu)$	$ADF(\tau_\mu)$		q	
	k=1	k=4	k=0	k=1	k=4	k=1	k=4
dp	—0.99	—1.03	—0.98	1.09	2.91	3.12	1.94
dpc	—1.76	—1.81	—1.64	0.47	2.87	0.23	—3.01
dpl	—1.49	—1.56	—1.44	0.19	1.81	0.02	—0.01
d^2p	—17.67	—19.04	—16.47*	—11.47	—4.29	—161.22	—169.02
d^2pc	—17.24	—19.43	—16.47*	—11.51	—4.83	—160.26	—168.54
d^2pl	—17.29	—20.51	—16.43*	—11.86	—5.87	—157.90	—167.12

T. 4.

Critical values

Test	10%	5%	1%
$z(\tau_\mu)$ ADF	—2.57	—2.86	—3.43
q	—11.2	—14.1	—20.6

Source: Fuller (1976),
Stock, Watson (1986).

The presence of units roots in quarterly series
(regression model 8)

T. 5.

Series	z (τ_i)		DF (τ_i)	q	
	k=1	k=4	k=0	k=1	k=4
personal consumption	—5.33	—5.31	—5.98*	—38.60	—66.46
public and government consumption	—7.96	—8.17	—6.17*	—45.41	—61.13
Import	—6.16	—6.21	—9.17*	—86.51	—82.58
Export	—6.09	—6.32	—9.29*	—87.92	—84.09
GNP	—9.76	—11.68	—7.58*	—62.81	—62.74

Note: Critical values are given in table 2.