ECON 343

Lecture 7: Application

Unit root and co-integration tests on the Lebanese public debt

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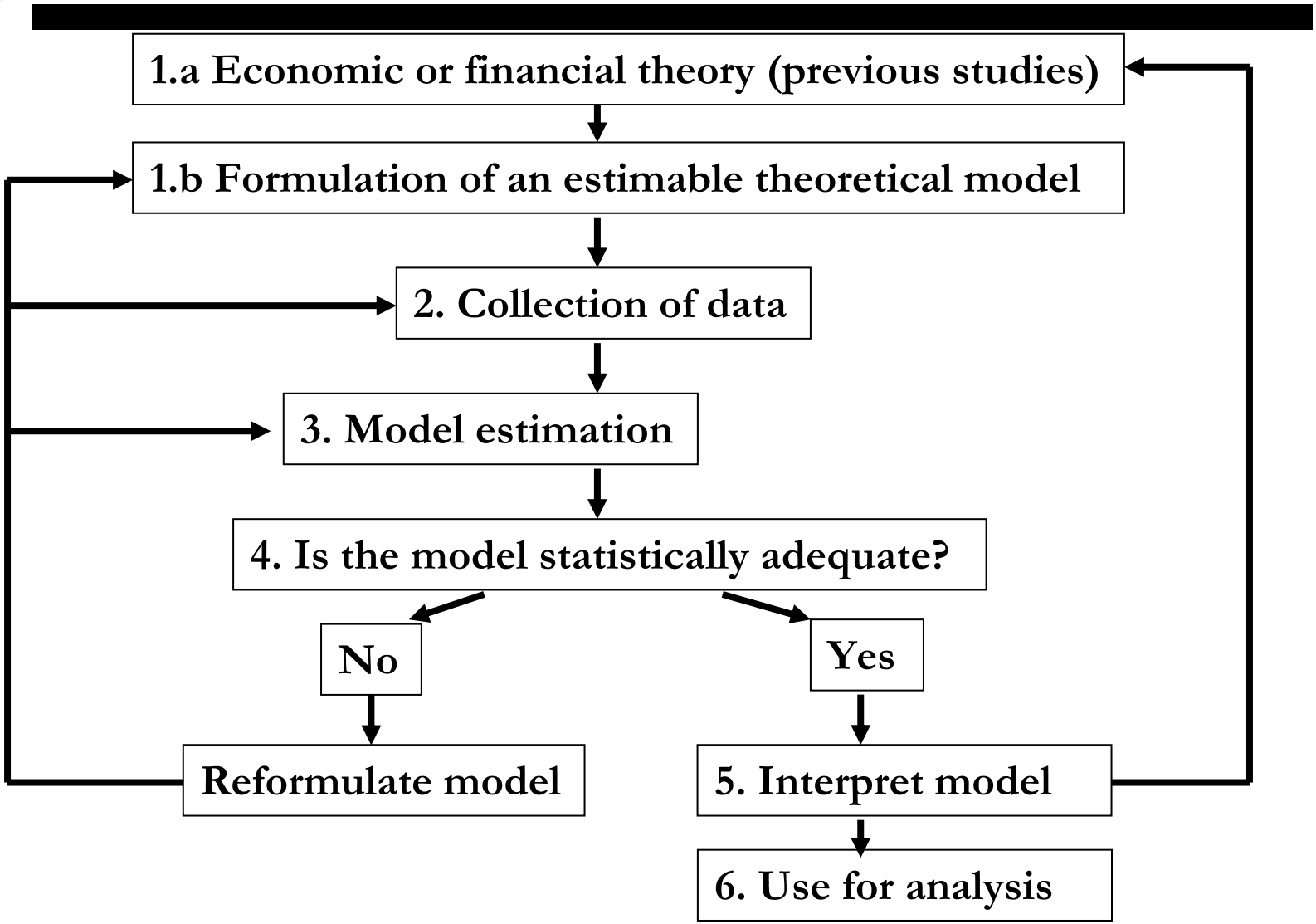
Spring 2005-2006

Outline – Lecture 7

1. Introduction
2. Fiscal and Macroeconomic Developments in Lebanon: 1970-2002
3. An Empirical Model For Optimal Government Spending
4. The Sustainability of Public Debt
5. Extension: monthly application in Eviews

Steps in an econometric model



1. Introduction

- Economists devoted to try and forecast whether budget deficits and total public debt are sustainable
- Debt not sustainable: reforming fiscal policies will be a must in avoiding a fiscal, monetary and exchange rate crisis
- Lebanon: permanent budget deficit for the past two decades for about 30 percent of GDP, resulting in a debt that is currently above 180 percent of GDP
- Inter-temporal budget constraint for the public sector:
  - Fiscal policy is sustainable when it is expected to generate sufficient net revenues in the future to repay the accumulated debt and its service

Introduction

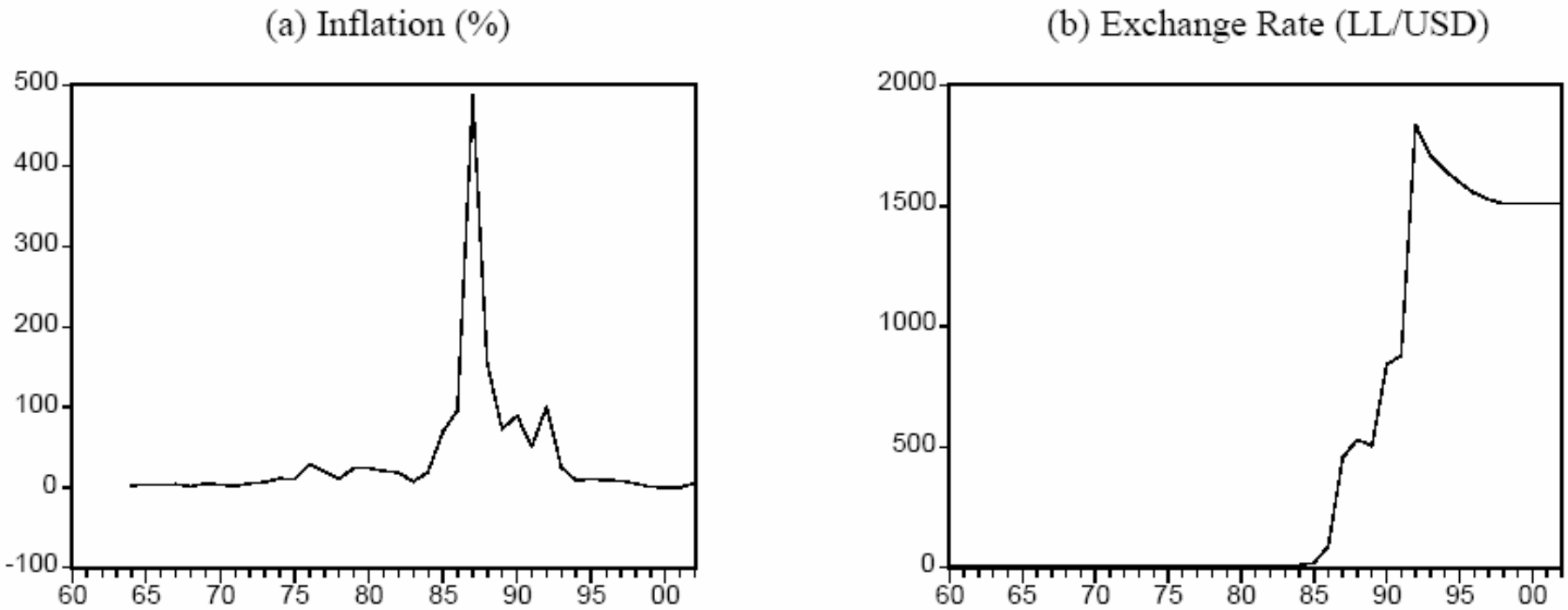
- External debt burden unsustainable:
  - when a given country will never be able to service its debt out of its own resources

- This paper:
  - What is the optimal level of Government spending?
  - How to evaluate public debt sustainability in Lebanon, using ratio analysis and the Present Value Constraint?
  - How to assess external debt sustainability using unit root and co-integration tests?

2. Fiscal and Macroeconomic Developments in Lebanon: 1970-2002

- War impact: 20 billion USD in infrastructure loss
- Post 1992: Banque Du Liban (BDL) was pursuing a conservative monetary policy with as target price and exchange rate stability
- Strict monetary policy was also exerting upward pressures on domestic interest rates.
- Instead of pursuing an accommodating monetary policy to ease up the upward pressure on domestic interest rates, BDL was reluctant to take that venue due to several episodes of political instability, and fears from a renewed devaluation of the local currency.
- The outcome of a restrictive monetary policy coupled with a heavy reliance on domestic credit was:
  - a sizeable public debt started to emerge coupled with
  - heavy service burden, which subsequently translated into recurrent budget deficits.

Figure 1. Inflation and Exchange Rates: 1960-2002



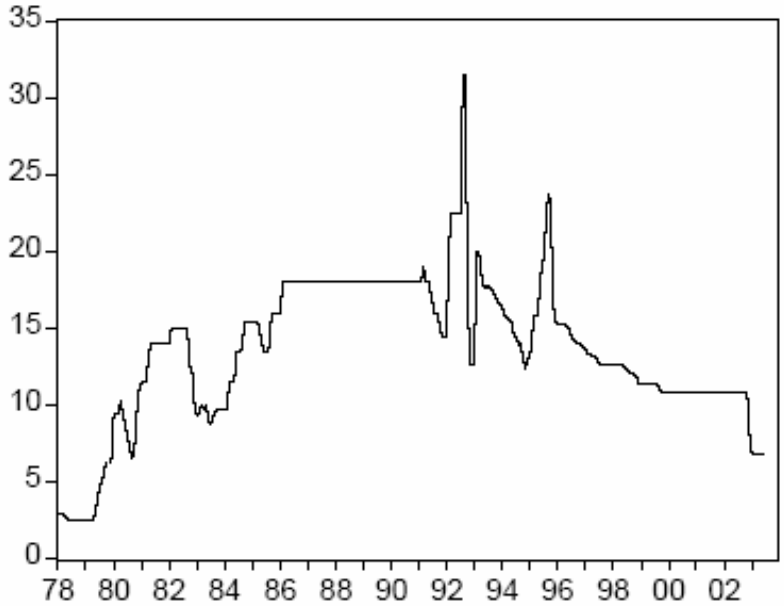
Source: Banque Du Liban (BDL), Lebanese Ministry of Finance and IMF.

The rate of inflation was at its highest historical levels of 400 percent, 99.79 percent and about 50 percent in 1989, 1990 and 1991 respectively. From about Lebanese Lira (LL) 3/USD prior to 1985, the exchange rate, by late 1992, shot up by 110 percent over its 1991 level to reach as high as L.L. 1838/USD

Figure 2. Nominal 3 Month Treasury Bills Rates and GDP

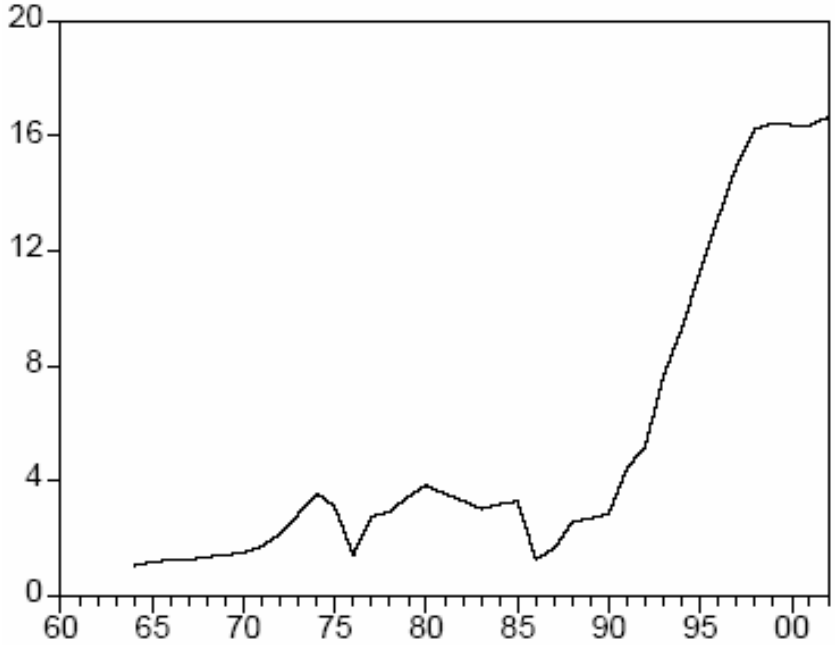
(a) Yearly Average TBs Rates

(b) Monthly TBs Rates

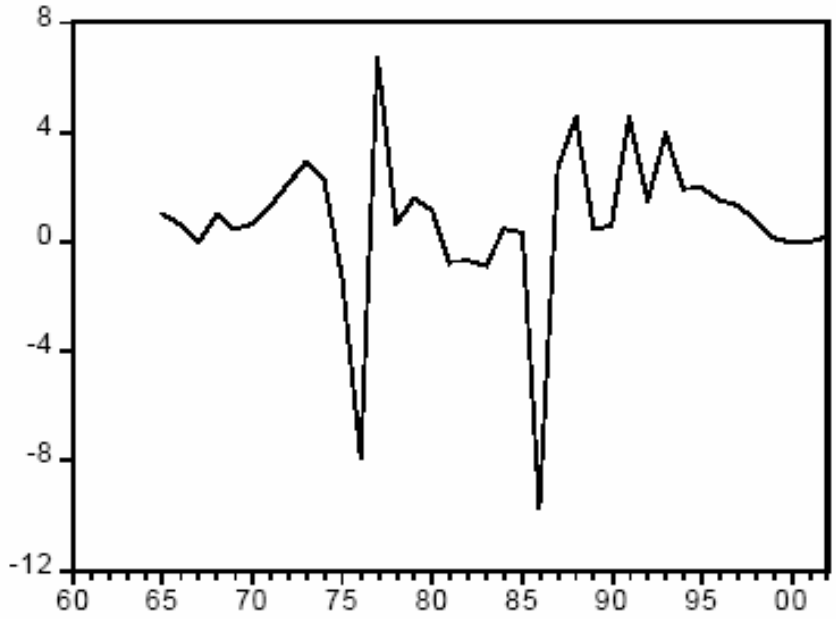


There was a reversal in the increasing trend of TB rates since end of 1996, and the real return on Lebanese treasury bills with maturities between 3, 6 and 24 month ranged between 12-18 percent. It goes above the US dollar and the Euro LIBOR (or risk free rate) by about 12-15 percent

(b) Nominal GDP in (USD Billion)



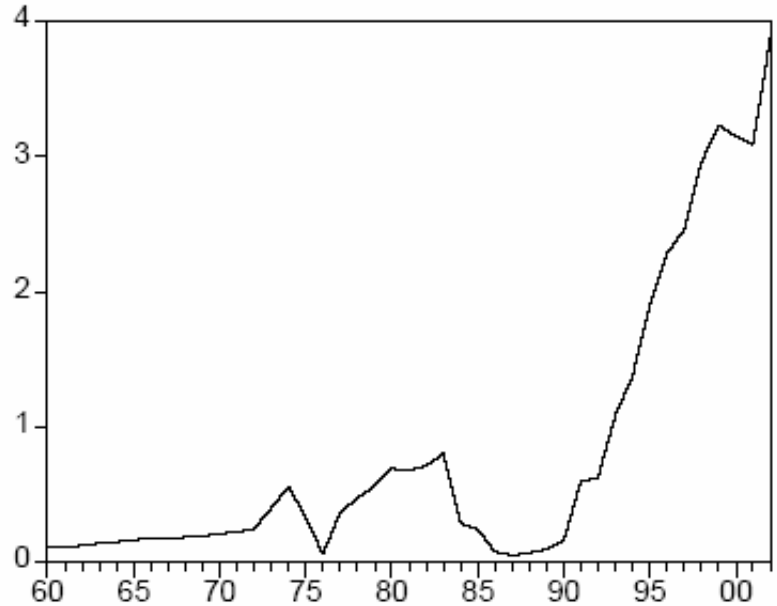
(c) Rate of Growth of Nominal GDP in (%)



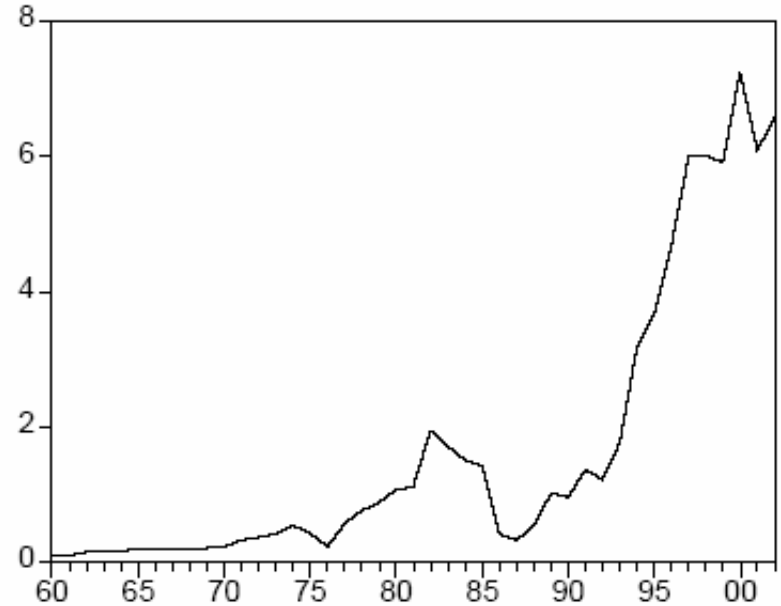
The debt and the need to finance it, have contributed to the early 2000s' recession (with an average growth in GDP of 1 percent) by the crowding out of private sector's investments subsequent to high interest rates peaking at 30 percent in 1993

Figure 3. Fiscal Developments: 1960-2002

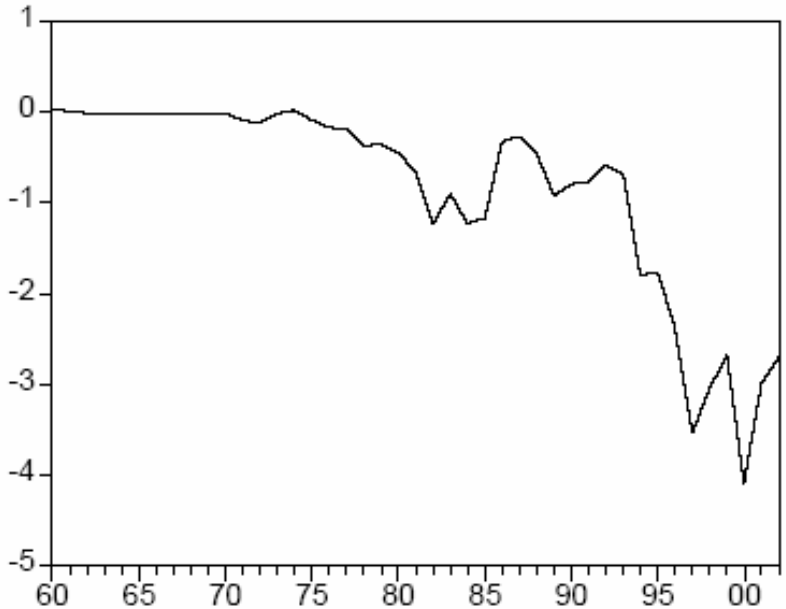
(a) Revenues in (USD Billion)



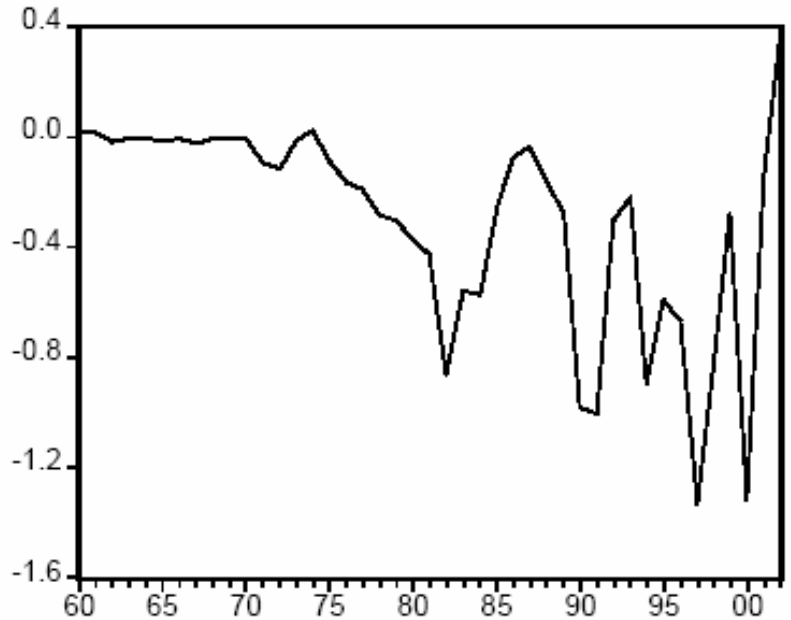
(b) Government Spending in (USD Billion)



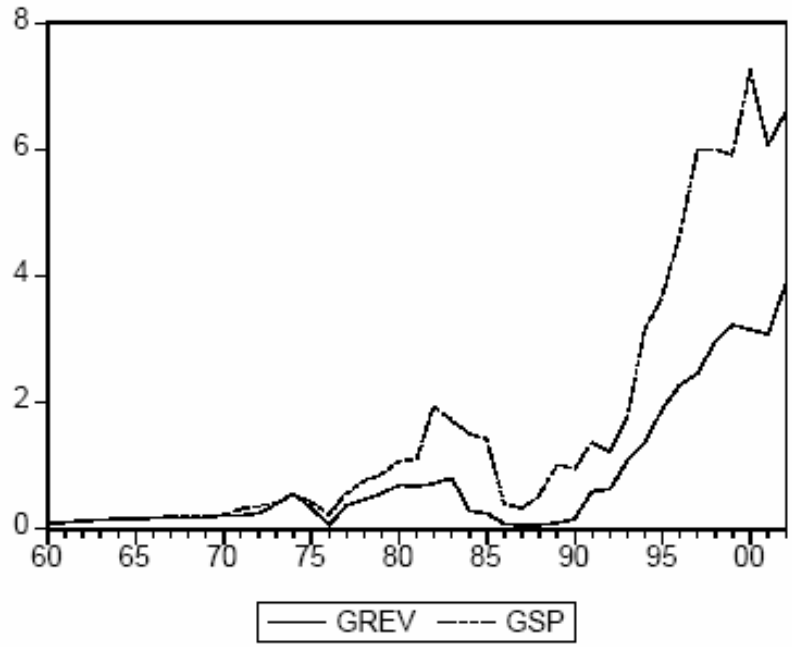
(c) Deficit or Surplus in (USD Billion)



(d) Primary Deficit or Surplus in (USD Billion)



(e) Government Spending (GSP) and Revenues (GREV) in (USD Billion)



(f) Budget Deficit/GDP in (%)

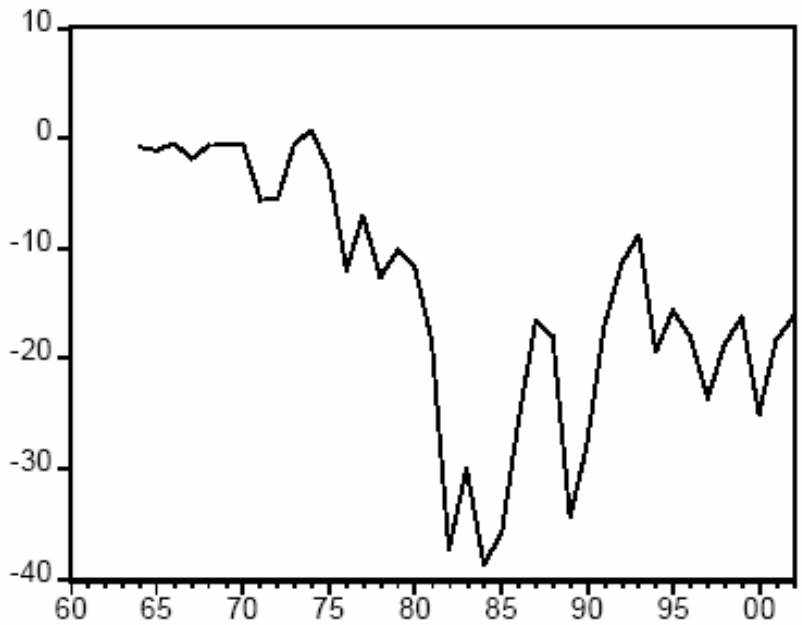
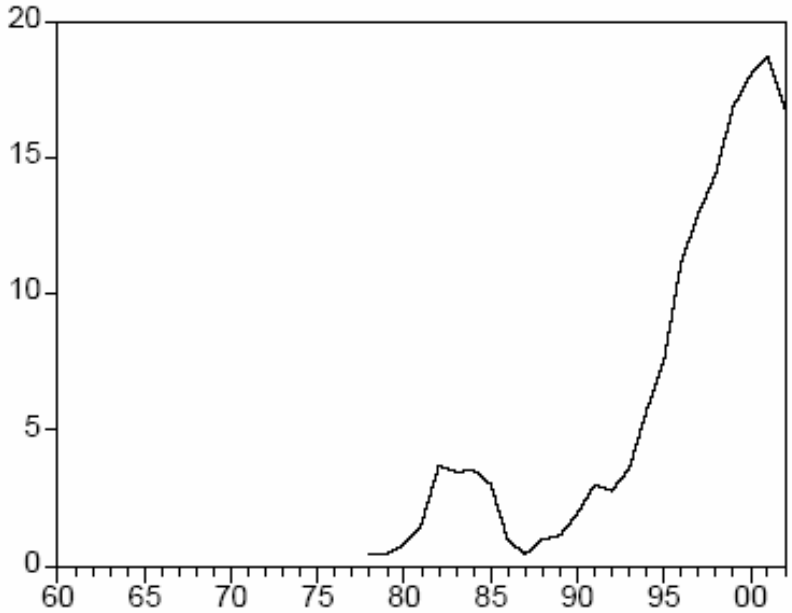
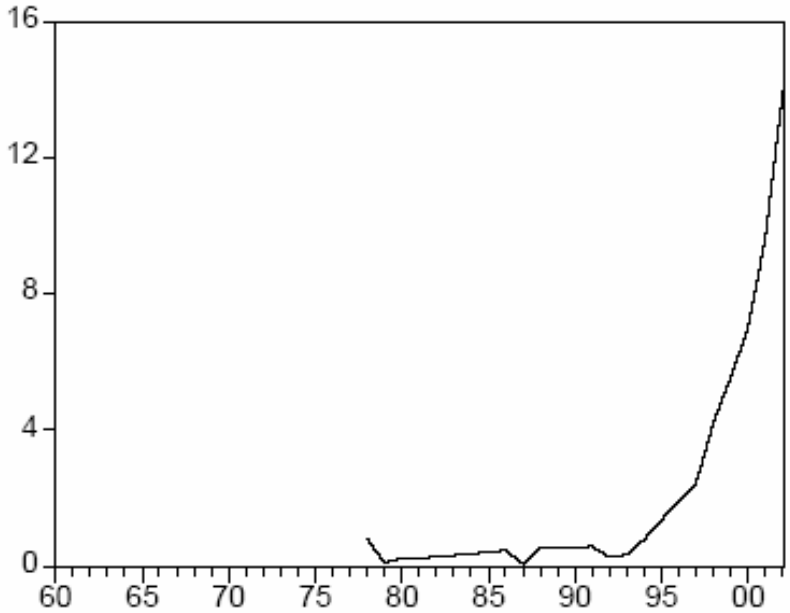


Figure 4. Evolution of Public Debt in Lebanon: 1960-2002

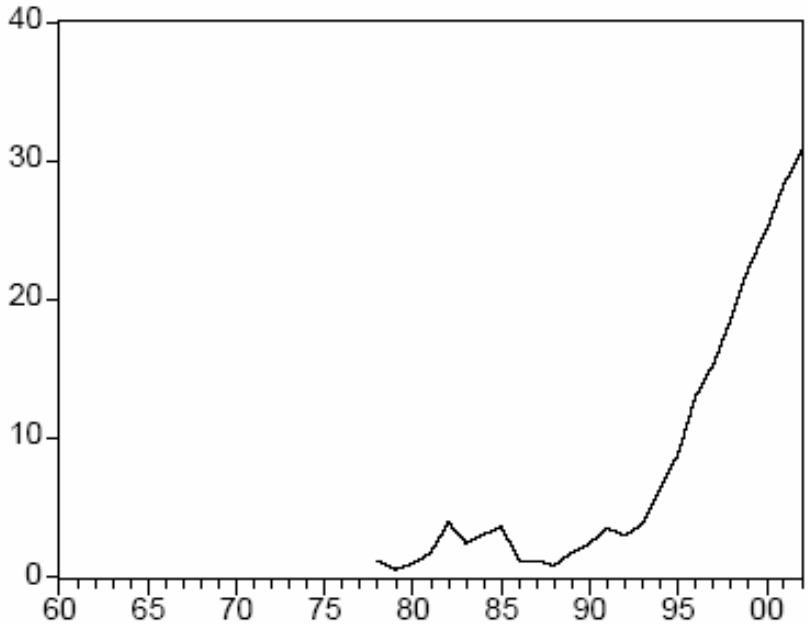
(a) Domestic Debt in (USD Billion)



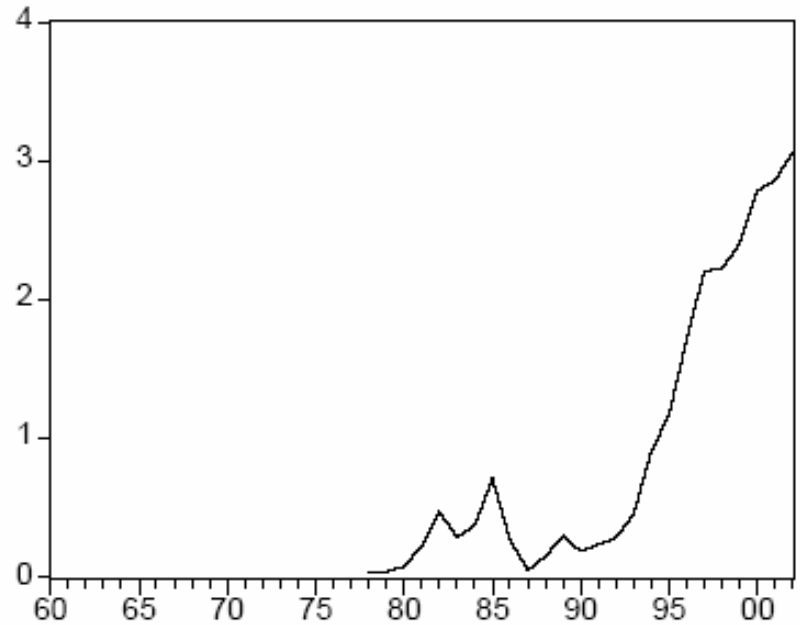
(b) External Debt in (USD Billion)



(c) Total Debt in (USD Billion)



(d) Debt Service in (USD Billion)



3. An Empirical Model For Optimal Government Spending

Following Vedder and Gallaway (1998), we estimate the following model for the Lebanese economy for the period 1964-2002, except for exports, which are tracked since 1981.

$$GDP = c_1 + c_2(G/GDP) - c_3(G/GDP)^2 + c_4(def) + c_5(def/gdp) + c_6(T/GDP) + c_7(X/GDP) + c_8(M2/GDP) + \varepsilon_t, \quad (9)$$

where GDP is the Gross Domestic Product; G/GDP is the ratio of government spending to GDP; $(G/GDP)^2$ is the squared ratio of government spending to GDP; *def* is the budget deficit; *def/GDP* is the ratio of the budget deficit to GDP; T/GDP is the ratio of government revenues to GDP; X/GDP is the ratio of exports to GDP; and M2/GDP is the ratio of M2 to GDP.

3. An Empirical Model For Optimal Government Spending

Before carrying out the estimation it is necessary to check the time series properties of each individual series by establishing their non-stationarity to avoid any problem of spurious regression. We use the ADF and PP unit root tests on each individual series. The unit root test results in Table 2 indicate that all series are non-stationary in levels and need to be differenced once to become stationary. That is all series are integrated of order one.

Table 2. Unit Root Tests

	GDP	G/ GDP	(G/ GDP)^2	M2/ GDP	Mackinnon's Critical Values 5 %	1%
Constant and Time Trend						
PP (3)	-1.01	-2.57	-2.72	-2.15	-3.51	-4.18
PP FD (3)	-4.10*	-5.34**	-5.74**	-6.70**	-3.52	-4.19
Constant						
PP (3)	0.60	-1.90	-2.30	-2.14	-2.93	-3.59
PP FD (3)	-3.79**	-5.43**	-5.86**	-6.79**	-2.93	-3.59
Constant and Time Trend						
ADF (1)	-1.14	-2.85	-2.56	-2.15	-3.52	-4.19
ADF FD (1)	-4.04*	-4.64**	-5.55**	-6.55**	-3.52	-4.20
Constant						
ADF (1)	0.32	-2.08	-2.19	-2.14	-2.93	-3.59
ADF FD (1)	-3.74**	-4.71**	-5.63**	-6.64**	-2.93	-3.60

Table 2 (Cont'd). Unit Root Tests

	Deficit	Deficit/ GDP	X/GDP	T/GDP	Mackinnon's Critical Values 5 %	1%
Constant and Time Trend						
PP (3)	-2.43	-2.40	-2.57	-2.27	-3.51	-4.18
PP FD (3)	-7.88**	-6.79**	-4.60**	-6.27**	-3.52	-4.19
Constant						
PP (3)	-0.72	-2.05	-1.52	-2.20	-2.93	-3.59
PP FD (3)	-7.81**	-6.83**	-4.80**	-6.28**	-2.93	-3.59
Constant and Time Trend						
ADF (1)	-2.04	-2.25	-2.74	-2.11	-3.52	-4.19
ADF FD (1)	-6.04**	-4.94**	-3.99*	-4.74**	-3.52	-4.20
Constant						
ADF (1)	-0.49	-2.02	-1.51	-2.01	-2.93	-3.59
ADF FD (1)	-5.82**	-4.97**	-4.41**	-4.72**	-2.93	-3.60

NOTES: 1- PP is the Phillips-Perron test; FD is the first difference; and ADF is Augmented Dickey Fuller. 2-The numbers in parenthesis are the proper lag lengths based on the Akaike Information Criterion (AIC). 3- A * indicates rejection of the null hypothesis of non-stationarity at the 5% level of significance, while ** indicates a stronger rejection at the 1% level. 4-For most variables the time trend variable is statistically insignificant at the 5%level, except for the GDP, deficit and X/GDP series.

We can therefore estimate next model (9) and the following adjustment is obtained

$$GDP = 5.37 + 1468.15(G/GDP) - 25.70(G/GDP)^2 + \ldots \quad (10)$$

R^2=0.97; DW= 2.29.

which gives an estimation of the order of 28.5 percent for the optimal level sought. This high level of government spending as a percent of GDP is not surprising and can be explained by the fact that in the last decade the growth rate of GDP has been mainly due to the large government spending on the devastated infrastructure. Most of the growth in GDP in the early and late 1990s was due to the huge government spending on the reconstruction efforts of the Lebanese government.

4. The Sustainability of Public Debt

The econometric tests to be carried out rest on the two frameworks advanced in the literature, that is stationarity and cointegration tests. If the total budget deficit is stationary, i.e., integrated of order zero, I(0) then according to Trehan and Walsh (1988, 1991) this constitute a sufficient condition to conclude that fiscal policy is sustainable. That is, the government deficit will not grow without bound, and the actual deficit will asymptotically converge to zero over time. The convergence to zero of the government deficit means that the PVC or the transversality condition in (14) is actually satisfied. In fact, an equivalent

Thus, we start by testing the non-stationarity of government total expenditures and revenues series. If the two series are stationary, i.e., are I(0) then the total budget is also stationary and the transversality condition will be satisfied, pointing to the sustainability of fiscal policy.

We establish stationarity or non–stationarity of the individual fiscal series by applying both the Phillips-Perron (PP) and Augmented Dickey–Fuller (ADF) unit root tests. The following regressions will be carried out

$$\Delta X_t = \beta_1 + \beta_2 X_{t-1} + \sum_{i=1}^{k} \delta_i \Delta X_{t-i} + \varepsilon_t, \qquad (18)$$

where Δ is the first–difference operator; $(X_{i,t})$ represents respectively the following fiscal time series for Lebanon: G (government spending); T (Tax Revenues), Total Deficit, and Total Debt, as well as the ratio of these variables to GDP ; β_i, δ_i, are constant parameters; and ε_t is a stationary stochastic process. The number of lags (k) will be determined based on the Akaike Information Criterion (AIC).

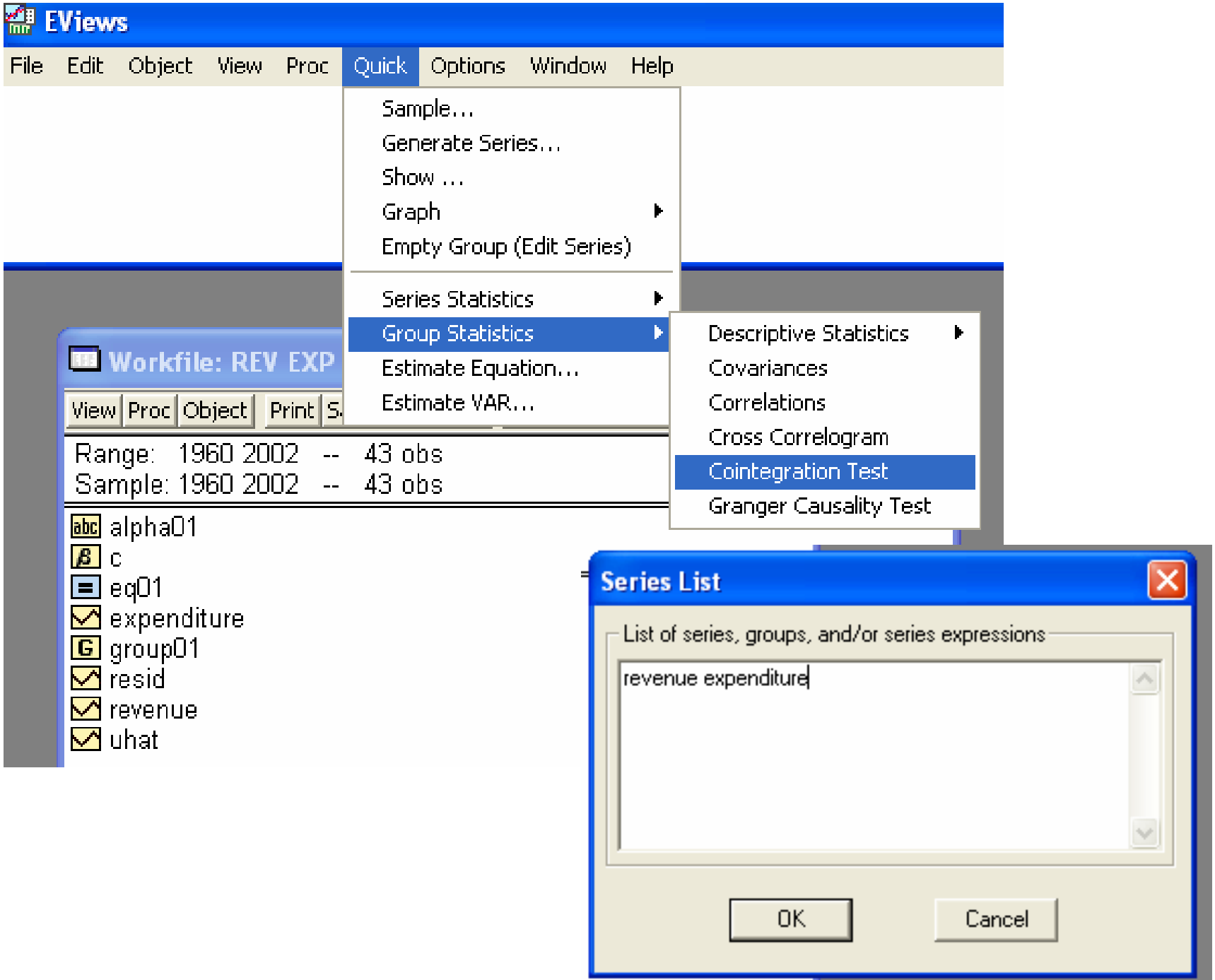
Table 3. Unit Roots Tests For Stationarity

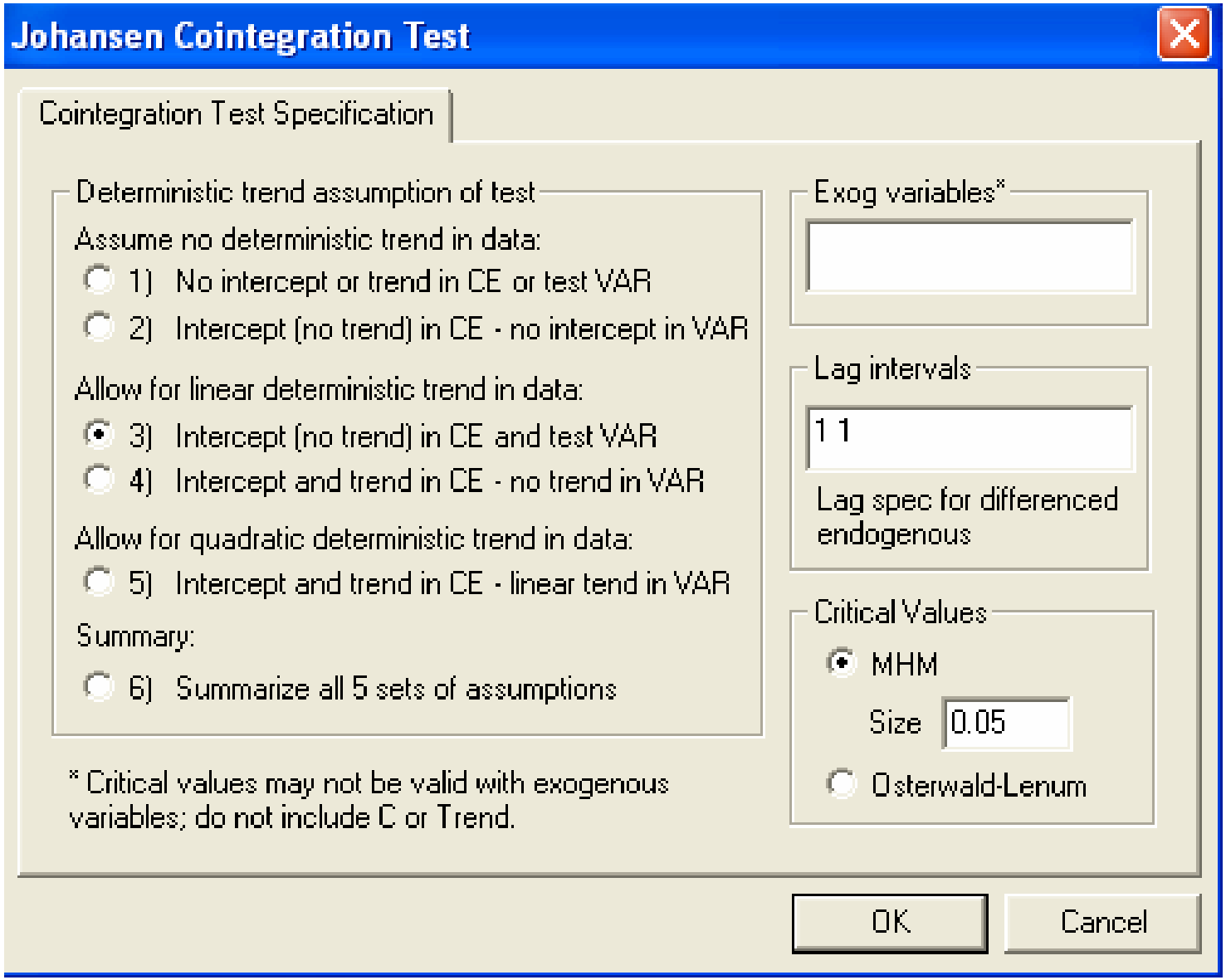
	G	G/ GDP	T	T/ GDP	Deficit	Deficit/ GDP	Debt	Debt/ GDP	Mackinnon's Critical Values 5 %	Mackinnon's Critical Values 1%
Constant and Time Trend										
PP (1)	-0.82	-2.60	0.50	-2.22	-2.36	-2.29	0.33	-1.72	-3.53	-4.21
PP FD (1)	-6.61**	-5.39**	-4.90**	-6.25**	-7.68**	-6.34**	-3.9*	-4.88**	-3.52	-4.19
Constant										
PP (1)	0.96	-1.95	2.37	-2.13	-0.72	-2.07	3.15*	-0.74	-2.93	-3.59
PP FD (1)	-6.15**	-5.47**	-3.96**	-6.26**	-7.68**	-6.38**		-4.99**	-2.94	-3.61
Constant and Time Trend										
ADF (1)	-0.79	-2.85	0.38	-2.10	-2.05	-2.16	0.51	-1.71	-3.52	-4.22
ADF FD (1)	-6.60**	-4.64**	-3.57*	-4.73**	-6.10**	-5.07**	-3.8*	-3.55*	-3.52	-4.20
Constant										
ADF (1)	0.90	-2.09	1.94	-2.01	-0.50	-2.00	3.7**	-1.08	-2.94	-3.61
ADF FD (1)	-6.14**	-4.71**	-2.70	-4.71**	-5.87**	-5.08**		-3.61**	-2.93	-3.60

NOTES: 1- PP is the Phillips-Perron test, FD is the first difference, and ADF is the Augmented Dickey Fuller. 2- The numbers in parenthesis are the proper lag lengths based on the Akaike Information Criterion (AIC).
3- A * indicates rejection of the null hypothesis of non-stationarity at the 5% level of significance, while ** indicates a stronger rejection at the 1% level. 4-When the series are taken as ratios to GDP the time trend becomes insignificant. The time trend is statistically significant for the debt series where the t-stats. is 2.57, and for both the G and T series the time trend is highly significant. For all series the constant is statistically insignificant.

Johansen co-integration

- When two series have no clear causal relationship
- Applied also with VAR models
- Easy to use with Eviews
- Gives number of co-integrating relationships (long run relationship) easily


EViews
File Edit Object View Proc Quick Options Window Help
Sample...
Generate Series...
Show ...
Graph
Empty Group (Edit Series)
Series Statistics
Group Statistics
Estimate Equation...
Estimate VAR...
Descriptive Statistics
Covariances
Correlations
Cross Correlogram
Cointegration Test
Granger Causality Test
Workfile: REV EXP
View Proc Object Print S
Range: 1960 2002 -- 43 obs
Sample: 1960 2002 -- 43 obs
alpha01
c
eq01
expenditure
group01
resid
revenue
uhat
Series List
List of series, groups, and/or series expressions
revenue expenditure
OK
Cancel


Johansen Cointegration Test
Cointegration Test Specification
Deterministic trend assumption of test
Assume no deterministic trend in data:
1) No intercept or trend in CE or test VAR
2) Intercept (no trend) in CE - no intercept in VAR
Allow for linear deterministic trend in data:
3) Intercept (no trend) in CE and test VAR
4) Intercept and trend in CE - no trend in VAR
Allow for quadratic deterministic trend in data:
5) Intercept and trend in CE - linear tend in VAR
Summary:
6) Summarize all 5 sets of assumptions
* Critical values may not be valid with exogenous variables; do not include C or Trend.
Exog variables*
Lag intervals
1 1
Lag spec for differenced endogenous
Critical Values
MHM
Size 0.05
Osterwald-Lenum
OK
Cancel

Group: UNTITLED Workfile: REV EXP YEARLY\Untitled

View | Proc | Object | Print | Name | Freeze | Sample | Sheet | Stats | Spec

Johansen Cointegration Test

Date: 04/05/06 Time: 17:12
Sample (adjusted): 1962 2002
Included observations: 41 after adjustments
Trend assumption: Linear deterministic trend
Series: REVENUE EXPENDITURE
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.237946	13.88722	15.49471	0.0861
At most 1	0.064782	2.745998	3.841466	0.0975

Trace test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Table 4. Cointegration Tests: Government Revenues and Expenditures

Hypothesis			Critical Values	
Null	Alternative	Trace Statistics	(5%)	(1%)
r=0	$r \geq 1$	13.88	15.14	20.04
$r \leq 1$	$r = 2$	2.74	3.76	6.65

NOTES: 1-The Johansen Cointegration Likelihood Ratio Test is based on the trace of the stochastic matrix.
2-The test allows for a linear deterministic trend in the data, and no constant.
3-r represents the number of cointegrating vectors. Maximum lag 1 year in VAR.
4-A **and * indicate significance at the 1 and 5% level of significance respectively. The asymptotic critical values are from Osterwald-Lenum (1992).

Table 5. Cointegration Tests: Government Revenues and Expenditures as Ratios to GDP

Hypothesis			Critical Values	
Null	Alternative	Trace Statistics	(5%)	(1%)
r=0	$r \geq 1$	6.84	12.53	16.31
$r \leq 1$	$r = 2$	0.14	3.84	6.51

NOTES: 1-The Johansen Cointegration Likelihood Ratio Test is based on the trace of the stochastic matrix.
2-The test allows for no deterministic trend or constant in the data, normalized to government revenues. 3-r represents the number of cointegrating vectors. Maximum lag 1 year in VAR.
4-A **and * indicate significance at the 1 and 5% level of significance respectively. 5-The asymptotic critical values are from Osterwald-Lenum (1992).

Augmented Dickey-Fuller Unit Root Test on REVENUE

Null Hypothesis: REVENUE has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic based on SIC, MAXLAG=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		0.617339	0.9993
Test critical values:	1% level	-4.192337	
	5% level	-3.520787	
	10% level	-3.191277	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Unit Root Test on EXPENDITURE

Null Hypothesis: EXPENDITURE has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic based on SIC, MAXLAG=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-0.851383	0.9521
Test critical values:	1% level	-4.192337	
	5% level	-3.520787	
	10% level	-3.191277	

*MacKinnon (1996) one-sided p-values.

Unit root tests on levels

Augmented Dickey-Fuller Unit Root Test on D(REVENUE)

Null Hypothesis: D(REVENUE) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic based on SIC, MAXLAG=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.911405	0.0015
Test critical values:	1% level	-4.198503	
	5% level	-3.523623	
	10% level	-3.192902	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Unit Root Test on D(EXPENDITURE)

Null Hypothesis: D(EXPENDITURE) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic based on SIC, MAXLAG=9)

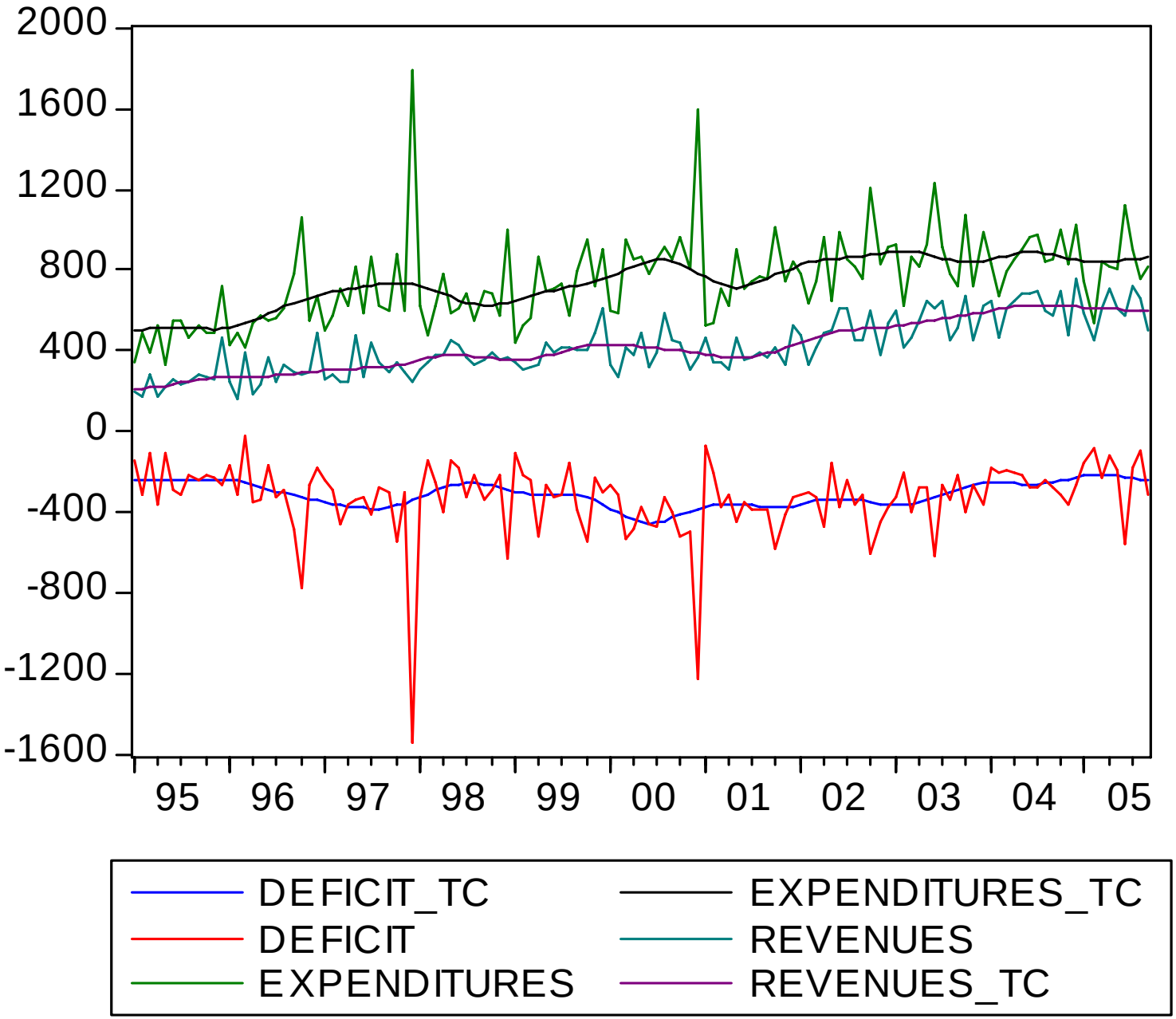
		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.610801	0.0000
Test critical values:	1% level	-4.198503	
	5% level	-3.523623	
	10% level	-3.192902	

*MacKinnon (1996) one-sided p-values.

Unit root tests on first difference: this is what is reported in the paper

Extension

- Monthly data on public finance
- Test sustainability of revenues and expenditures
- Co-integration test


2000
1600
1200
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0
-400
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02
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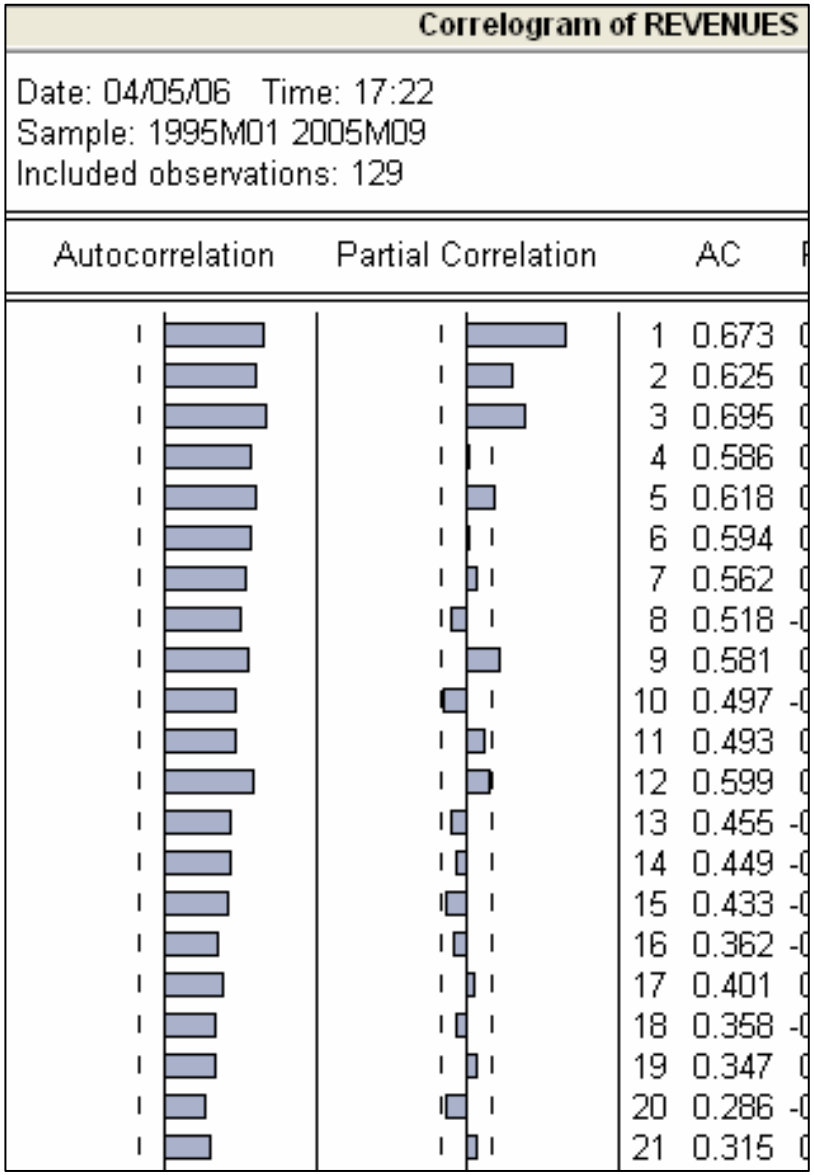
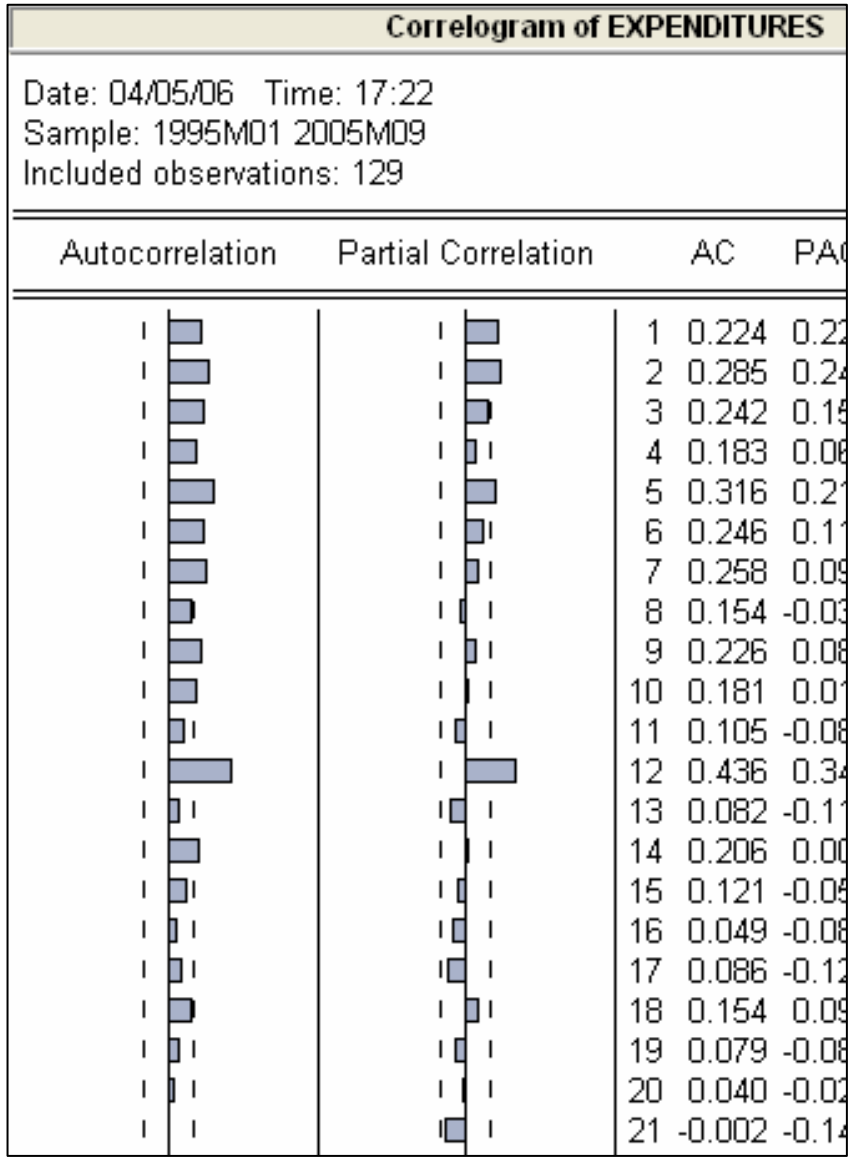
EXPENDITURES_TC
REVENUES
REVENUES_TC


Correlogram of REVENUES
Date: 04/05/06 Time: 17:22
Sample: 1995M01 2005M09
Included observations: 129
Autocorrelation
Partial Correlation
AC
1 0.673
2 0.625
3 0.695
4 0.586
5 0.618
6 0.594
7 0.562
8 0.518
9 0.581
10 0.497
11 0.493
12 0.599
13 0.455
14 0.449
15 0.433
16 0.362
17 0.401
18 0.358
19 0.347
20 0.286
21 0.315


Correlogram of EXPENDITURES
Date: 04/05/06 Time: 17:22
Sample: 1995M01 2005M09
Included observations: 129
Autocorrelation
Partial Correlation
AC
1 0.224
2 0.285
3 0.242
4 0.183
5 0.316
6 0.246
7 0.258
8 0.154
9 0.226
10 0.181
11 0.105
12 0.436
13 0.082
14 0.206
15 0.121
16 0.049
17 0.086
18 0.154
19 0.079
20 0.040
21 -0.002

Augmented Dickey-Fuller Unit Root Test on REVENUES

Null Hypothesis: REVENUES has a unit root
Exogenous: Constant
Lag Length: 4 (Automatic based on SIC, MAXLAG=12)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.371245	0.5944
Test critical values:	1% level	-3.483751	
	5% level	-2.884856	
	10% level	-2.579282	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Unit Root Test on EXPENDITURES

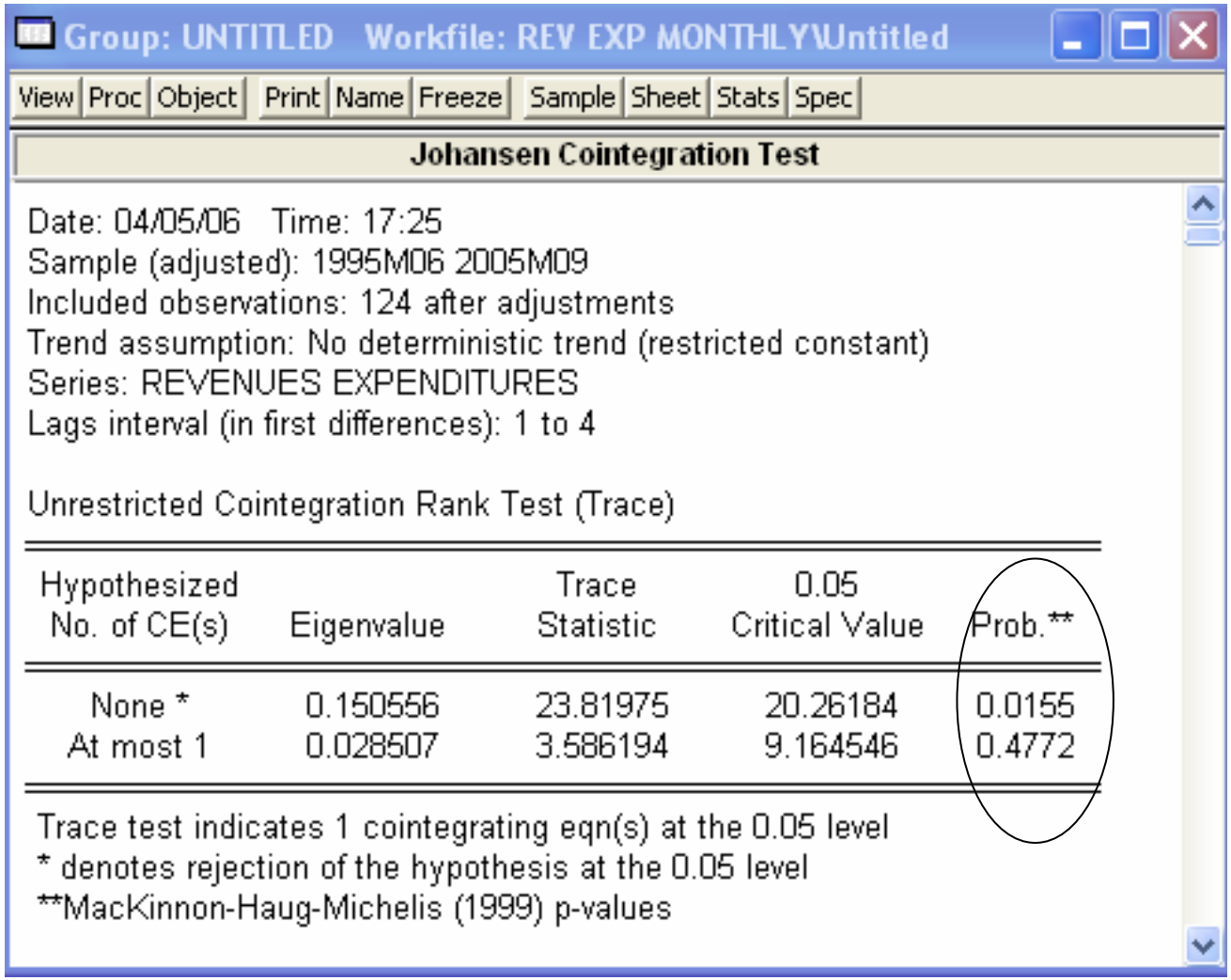
Null Hypothesis: EXPENDITURES has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic based on SIC, MAXLAG=12)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-9.067811	0.0000
Test critical values:	1% level	-3.482035	
	5% level	-2.884109	
	10% level	-2.578884	

*MacKinnon (1996) one-sided p-values.

Not same order of integration

No cointegration found when only the constant is included



Augmented Dickey-Fuller Unit Root Test on REVENUES

Null Hypothesis: REVENUES has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic based on SIC, MAXLAG=12)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-10.67469	0.0000
Test critical values:	1% level	-4.031309	
	5% level	-3.445308	
	10% level	-3.147545	

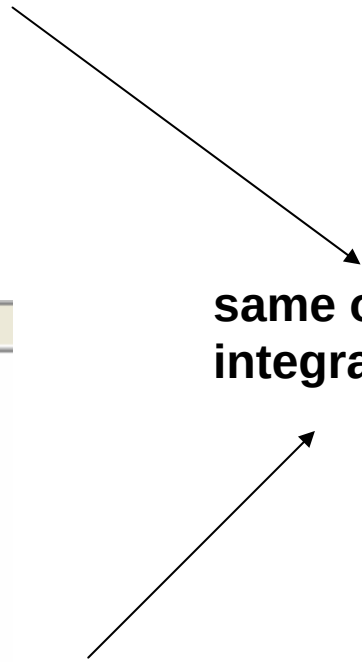
*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Unit Root Test on EXPENDITURES

Null Hypothesis: EXPENDITURES has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic based on SIC, MAXLAG=12)

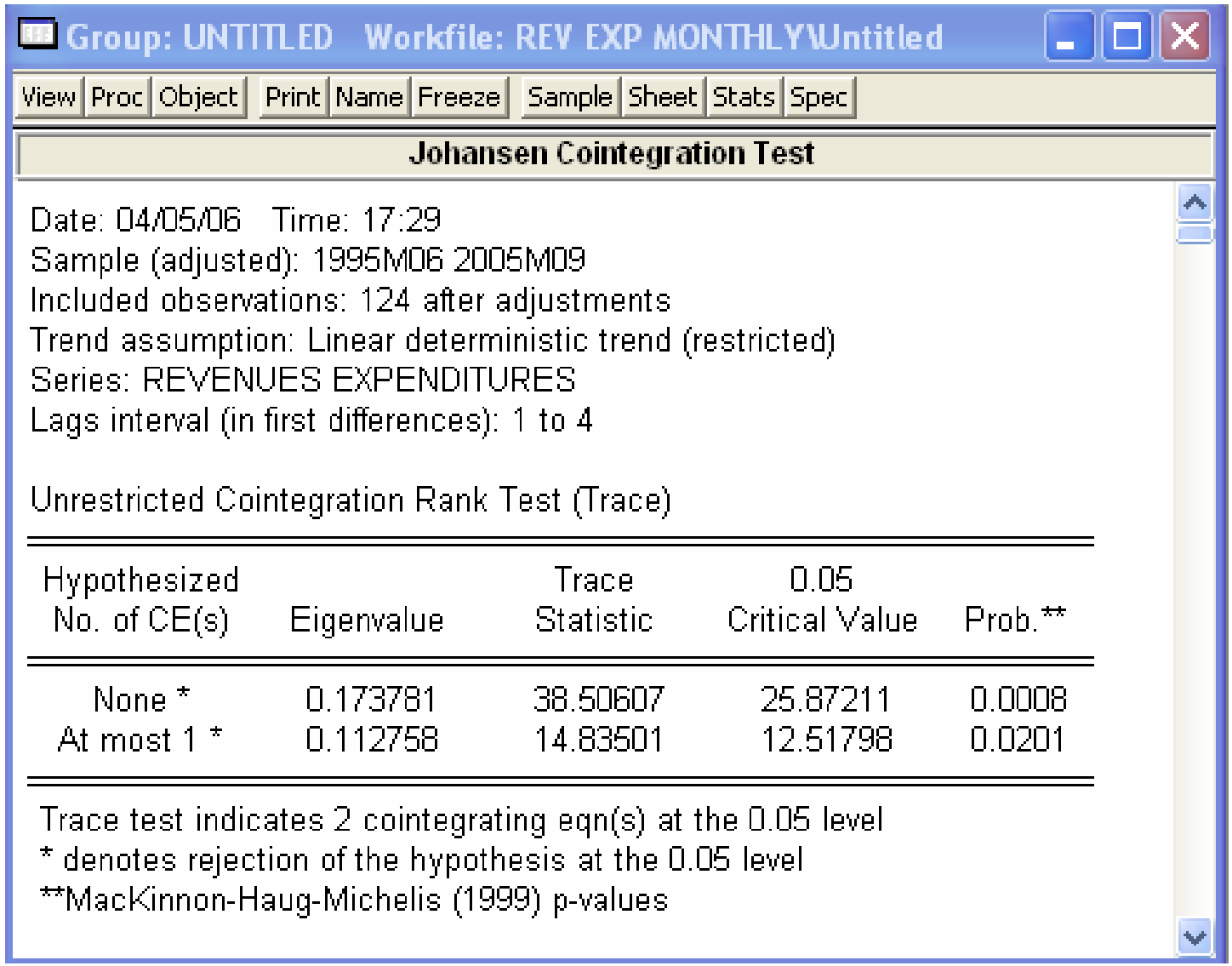
		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-11.66105	0.0000
Test critical values:	1% level	-4.031309	
	5% level	-3.445308	
	10% level	-3.147545	

*MacKinnon (1996) one-sided p-values.



same order of integration I(0)

Cointegration is found when the constant and time trend are included



Group: UNTITLED Workfile: REV EXP MONTHLY\Untitled

View | Proc | Object | Print | Name | Freeze | Sample | Sheet | Stats | Spec

Johansen Cointegration Test

Date: 04/05/06 Time: 17:29
Sample (adjusted): 1995M06 2005M09
Included observations: 124 after adjustments
Trend assumption: Linear deterministic trend (restricted)
Series: REVENUES EXPENDITURES
Lags interval (in first differences): 1 to 4

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.173781	38.50607	25.87211	0.0008
At most 1 *	0.112758	14.83501	12.51798	0.0201

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values