```
* Choose "File-Clear Program" before you do the following.

All 1000

******** U = white noise Process ***************************

* U = White noise process

set U = %ran(1)
(1)(2) correlate(partial=PACF, QSTATS) U / ACF
(G1) graph(key=below,style=bar,nodates,min=-1.0,max=1.0,number=1) 2
# ACF
# PACF

******** Y = AR(1) Process **************************

* Generating the data and plot

set y = 0
set y 2 * =  0 + 0.5 * y{1} + %ran(1)

(not printed) graph(key=below, header = 'y(t): AR(1) Model with alpha = 0.5') 1
# y

* Finding ACF and plot

(3)(4) correlate(QSTATS, Partial=PACF) y / ACF

(G2) graph(key=below,style=bar,nodates,min=-1.0,max=1.0,number=1, $
 header = 'ACF of y(t): AR(1) Model with alpha = 0.99') 2
# ACF
# PACF

* Estimating the model

(5) boxjenk(constant, ar=1) y / resids

* Checking the residual

(6) cor(partial=pacf,qstats,number=48,span=8,dfc=%nreg) resids / ACF

(not printed) graph(key=below,style=bar,nodates,min=-1.0,max=1.0,number=1, $
 header = 'ACF of Residauls: AR(1) Model with alpha = 0.5') 2
# ACF
# PACF

******** Y = MA(1) Process **************************

* Generating the data and plot

set U = %ran(1)
set y = 0 + U + 0.5 * u{1}

(not printed) graph(key=below, header = 'y(t): MA(1) Model') 1
# y

* Finding ACF and plot

(7)(8) correlate(QSTATS) Y / ACF

(G3) graph(key=below,style=bar,min=-1.0,max=1.0,number=1, $
  header = 'ACF and PACF of y(t): MA(1) Model with theta = 0.5') 2
# ACF
# PACF

* Estimating the model

(9) boxjenk(constant, ma=1) y / resids
```

```
* Checking the residual

cor(partial=pacf,qstats,number=48,span=8,dfc=%nreg) resids / ACF

graph(key=below,style=bar,nodates,min=-1.0,max=1.0,number=1, $
 header = 'ACF and PACF of residuals: MA(1) Model with theta = 0.5') 2
# ACF
# PACF
```

```
Correlations of Series U
Autocorrelations
    1:  0.0302111 -0.0354111 -0.0027542  0.0227238 -0.0274777 -0.0355858
    -0.0250347  0.0093958 -0.0035661 -0.0402481  0.0216983
   12: -0.0050943  0.0078096 -0.0393766 -0.0284638  0.0129991 -0.0031584
   0.0239753 -0.0311927 -0.0016837  0.0130694  0.0391151
   23: -0.0251518 -0.0920112 -0.0270277  0.0437092 -0.0204225 -0.0060681
   -0.0636930 -0.0338707 -0.0379460  0.0370562  0.0115742
   34: -0.0103040 -0.0625784 -0.0377235 -0.0577013 -0.0499946  0.0071115
   -0.0171968 -0.0065343 -0.0203834  0.0042435 -0.0157062
   45:  0.0330528  0.0120145  0.0242370 -0.0135660  0.0327486  0.0119414
   0.0152129  0.0455663 -0.0219800 -0.0249968  0.0251582
   56:  0.0007814  0.0513536  0.0186980  0.0957647  0.0543999  0.0078088
   0.0007897 -0.0025222

Partial Autocorrelations
    1:  0.0302111 -0.0363570 -0.0005483  0.0215879 -0.0290609 -0.0323458
    -0.0249076  0.0079489 -0.0047968 -0.0390273  0.0232128
   12: -0.0122418  0.0087039 -0.0392485 -0.0287705  0.0109760 -0.0075992
   0.0285460 -0.0351924 -0.0033276  0.0098744  0.0356612
   23: -0.0225678 -0.0937257 -0.0246586  0.0382374 -0.0214789  0.0038994
   -0.0780960 -0.0392158 -0.0432991  0.0441011  0.0049457
   34: -0.0242536 -0.0657691 -0.0416346 -0.0637454 -0.0589503 -0.0061890
   -0.0250064 -0.0131481 -0.0266050 -0.0196087 -0.0407599
   45:  0.0270992  0.0113597  0.0203838 -0.0396776  0.0230683  0.0006828
   0.0192830  0.0398650 -0.0370216 -0.0454695  0.0240439
   56:  0.0041906  0.0684651  0.0025001  0.0915761  0.0381908  0.0077120
   0.0061485 -0.0038372

Ljung-Box Q-Statistics
Q(63-0)=           71.2108.  Significance Level 0.22340907

Correlations of Series Y
Autocorrelations
    1:  0.5287665  0.3093883  0.1949128  0.0846160  0.0486042  0.0575407
    -0.0047278  0.0024138  0.0058447  0.0312111  0.0348051
   12:  0.0569040  0.0453921  0.0015850 -0.0056936 -0.0002633  0.0132364
   0.0234644  0.0580260  0.0349873  0.0225101  0.0093011
   23:  0.0255260 -0.0138366 -0.0125512 -0.0002903 -0.0183257 -0.0116955
   0.0367366 -0.0045059 -0.0196991 -0.0566468 -0.0882536
   34: -0.0794629 -0.0425047 -0.0445979 -0.0273268  0.0105230 -0.0057571
   -0.0258291 -0.0355688 -0.0085061  0.0126886  0.0179074
   45:  0.0008506  0.0039694  0.0409335  0.0194987  0.0201010  0.0421353
   0.0140961 -0.0139057 -0.0196166 -0.0230040 -0.0197696
   56: -0.0133864  0.0271633  0.0457927  0.0545080  0.0844373  0.1081481
   0.0813829  0.0351739

Partial Autocorrelations
    1:  0.5287665  0.0413576  0.0225480 -0.0489494  0.0150935  0.0427726
    -0.0679016  0.0259314  0.0027484  0.0449641 -0.0003303
   12:  0.0362225 -0.0027101 -0.0482589  0.0046981  0.0082866  0.0267263
   0.0050319  0.0546768 -0.0238966 -0.0052769 -0.0136995
   23:  0.0326913 -0.0506209  0.0031670  0.0243403 -0.0249154  0.0071808
   0.0489876 -0.0505347 -0.0248015 -0.0575027 -0.0320066
   34: -0.0024413  0.0212572 -0.0174348  0.0085792  0.0355739 -0.0342699
   -0.0291758 -0.0265170  0.0411489  0.0330326  0.0046340
   45: -0.0156279  0.0098626  0.0561425 -0.0500578  0.0167124  0.0369812
   -0.0147679 -0.0302180  0.0033215  0.0000217 -0.0115865
   56:  0.0014379  0.0499169  0.0213831  0.0182311  0.0497947  0.0520862
   -0.0122997 -0.0465078

Ljung-Box Q-Statistics
Q(63-0)=          511.2254.  Significance Level 0.00000000

Box-Jenkins - Estimation by Gauss-Newton
```

4

```
Convergence in     3 Iterations. Final criterion was  0.0000000 <=  0.0000100
Dependent Variable Y
Usable Observations    999      Degrees of Freedom   997
Centered R**2      0.279595     R Bar **2   0.278872
Uncentered R**2    0.279606     T x R**2    279.327
Mean of Dependent Variable      0.0045137776
Std Error of Dependent Variable 1.1440364260
Standard Error of Estimate      0.9715069616
Sum of Squared Residuals        940.99429918
Regression F(1,997)                 386.9437
Significance Level of F           0.00000000
Log Likelihood                   -1387.64065
Durbin-Watson Statistic             2.040117
Q(36-1)                            40.627800
Significance Level of Q           0.23624940

   Variable                     Coeff       Std Error      T-Stat     Signif
*******************************************************************************
*
1.  CONSTANT                0.0026469553 0.0653051330      0.04053
0.96767702
2.  AR{1}                   0.5293284750 0.0269092372     19.67088
0.00000000
```

(6)

```
Correlations of Series RESIDS
Autocorrelations
     1: -0.0218907  0.0183848  0.0570091 -0.0284451 -0.0180783  0.0699851
     -0.0523892  0.0034471 -0.0143257  0.0256067 -0.0028686
    12:  0.0421955  0.0377415 -0.0262966 -0.0110683 -0.0060173  0.0064894
    -0.0106505  0.0602138  0.0029507  0.0075110 -0.0186681
    23:  0.0487687 -0.0341097 -0.0118100  0.0222041 -0.0236097 -0.0343000
    0.0771129 -0.0204948  0.0099085 -0.0214256 -0.0571567
    34: -0.0452950  0.0152276 -0.0280642 -0.0235486  0.0429695  0.0008816
    -0.0153649 -0.0379654  0.0016642  0.0158380  0.0221773
    45: -0.0142973 -0.0236505  0.0551428 -0.0104185

Partial Autocorrelations
     1: -0.0218907  0.0179142  0.0578428 -0.0263556 -0.0215304  0.0672794
     -0.0460407  0.0001064 -0.0209908  0.0340719 -0.0014672
    12:  0.0368604  0.0423316 -0.0283685 -0.0146790 -0.0136380  0.0168817
    -0.0149655  0.0594337  0.0102125  0.0074461 -0.0269872
    23:  0.0452485 -0.0284523 -0.0246475  0.0244968 -0.0156597 -0.0270876
    0.0613225 -0.0049690  0.0029497 -0.0391431 -0.0516608
    34: -0.0408994  0.0085791 -0.0173539 -0.0193812  0.0434596  0.0040262
    -0.0128415 -0.0550415 -0.0055265  0.0279041  0.0278448
    45: -0.0059599 -0.0232228  0.0700049 -0.0219711


Ljung-Box Q-Statistics
Q(8-2) =          12.9354.  Significance Level 0.04407284
Q(16-2)=          17.9260.  Significance Level 0.21017292
Q(24-2)=          25.8376.  Significance Level 0.25871811
Q(32-2)=          35.4126.  Significance Level 0.22793865
Q(40-2)=          44.7236.  Significance Level 0.21027990
Q(48-2)=          51.1178.  Significance Level 0.27963326
```

(7)

```
Correlations of Series Y
Autocorrelations
     1:  0.4215988  0.0548262  0.0136375  0.0234858  0.0284238  0.0044800
     0.0304867  0.0388826 -0.0070168 -0.0052288  0.0005868
    12:  0.0060454  0.0091547 -0.0004414 -0.0196961 -0.0138172 -0.0601417
    -0.1039388 -0.0818042 -0.0383387 -0.0209678 -0.0017336
    23:  0.0304517  0.0263581  0.0099269 -0.0153190  0.0067315  0.0401272
    0.0111132 -0.0144390 -0.0294126  0.0151961  0.0370748
    34: -0.0040677  0.0339948  0.0623221  0.0483396  0.0236767 -0.0129814
    -0.0018250  0.0104958 -0.0337416  0.0126132  0.0582014
    45:  0.0606123  0.0076619 -0.0125894 -0.0110542 -0.0469353 -0.0523560
    -0.0207896  0.0058792 -0.0390148 -0.0534738 -0.0447268
```

5

```
    56: -0.0321214 -0.0253292 -0.0020671 -0.0227911 -0.0191999  0.0198732
    -0.0208378 -0.0347100
```

(8)

```
Ljung-Box Q-Statistics
Q(63-0)=         251.0443.  Significance Level 0.00000000
```

(9)

```
Box-Jenkins - Estimation by Gauss-Newton
Convergence in     6 Iterations. Final criterion was  0.0000018 <=  0.0000100
Dependent Variable Y
Usable Observations     999      Degrees of Freedom   997
Centered R**2      0.195990      R Bar **2   0.195183
Uncentered R**2    0.209590      T x R**2     209.381
Mean of Dependent Variable       -0.143068181
Std Error of Dependent Variable   1.091216242
Standard Error of Estimate        0.978947188
Sum of Squared Residuals        955.46258407
Log Likelihood                  -1395.26229
Durbin-Watson Statistic            1.940109
Q(36-1)                           28.774489
Significance Level of Q            0.76189440

   Variable                        Coeff        Std Error      T-Stat     Signif
********************************************************************************
*
1.  CONSTANT                    -0.145143795  0.045461826     -3.19265
0.00145386
2.  MA{1}                        0.468481569  0.028042383     16.70620
0.00000000
```

(10)

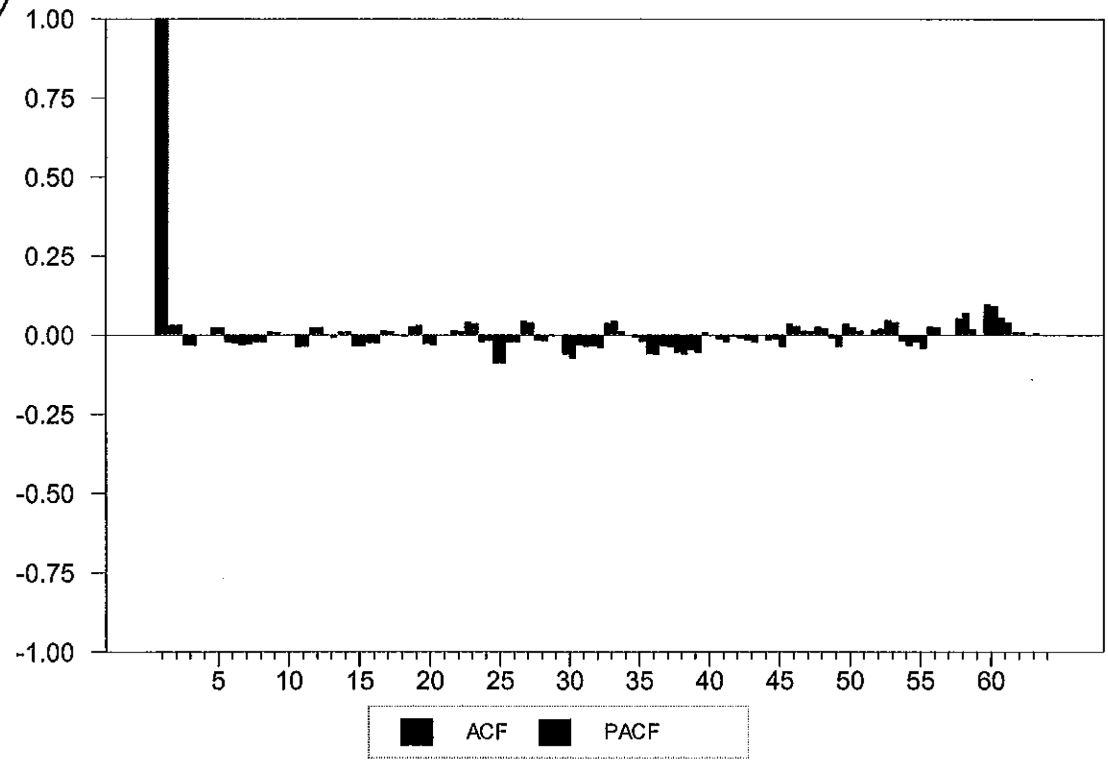
```
Correlations of Series RESIDS
Autocorrelations
     1:  0.0269757  0.0508220 -0.0127863  0.0184143  0.0265566 -0.0132526
     0.0210596  0.0415803 -0.0237798  0.0068462 -0.0049634
    12:  0.0056035  0.0025076  0.0099884 -0.0288330  0.0119730 -0.0382425
    -0.0722561 -0.0508931 -0.0152215 -0.0120743 -0.0095142
    23:  0.0303949  0.0103390  0.0126228 -0.0209791 -0.0035133  0.0438443
    -0.0077553  0.0011355 -0.0346021  0.0111223  0.0466763
    34: -0.0338448  0.0321764  0.0417027  0.0253570  0.0217385 -0.0178985
    -0.0084325  0.0362528 -0.0565035  0.0239597  0.0302378
    45:  0.0537566 -0.0066873 -0.0122140  0.0084366

Partial Autocorrelations
     1:  0.0269757  0.0501308 -0.0154910  0.0166598  0.0271633 -0.0167100
     0.0197550  0.0427362 -0.0296764  0.0045221 -0.0010208
    12:  0.0014501  0.0021750  0.0117071 -0.0326206  0.0123043 -0.0340635
    -0.0747833 -0.0424383 -0.0058849 -0.0108222 -0.0042335
    23:  0.0391057  0.0080543  0.0154515 -0.0150502 -0.0039892  0.0443709
    -0.0081714 -0.0049846 -0.0319723  0.0112291  0.0452478
    34: -0.0363272  0.0242637  0.0357550  0.0108864  0.0154680 -0.0183845
    -0.0170872  0.0405444 -0.0515383  0.0214697  0.0355953
    45:  0.0495697 -0.0109782 -0.0076178  0.0055290
```

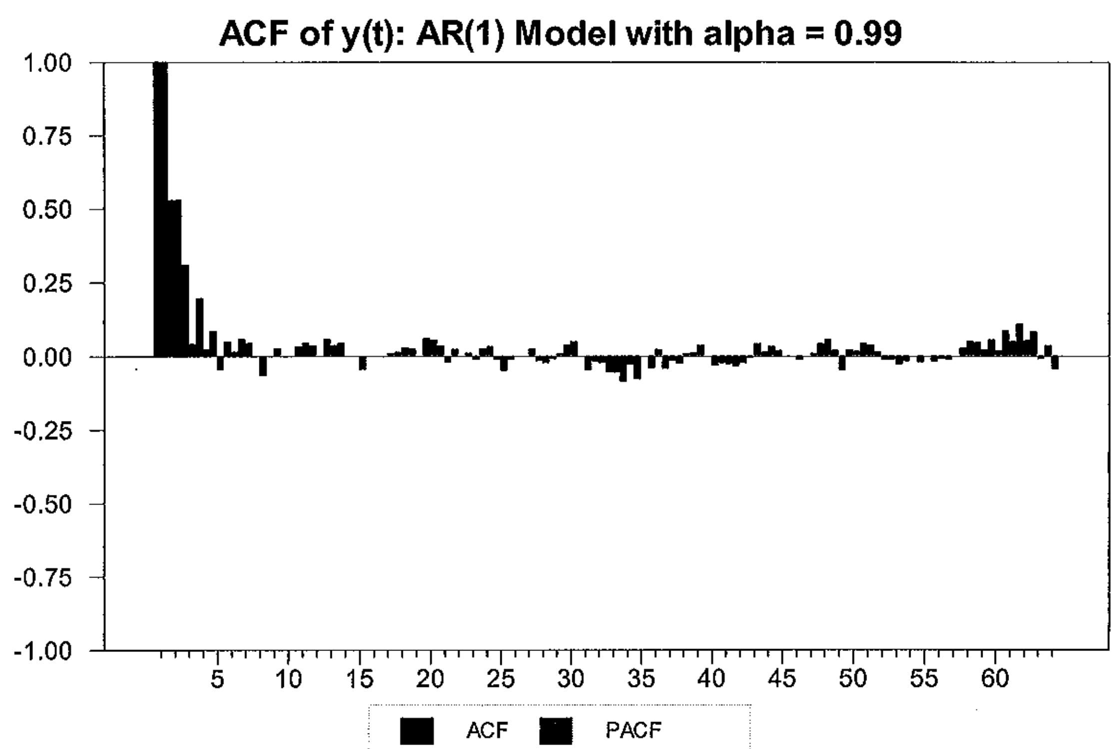
(11)

```
Ljung-Box Q-Statistics
Q(8-2) =           6.9028.  Significance Level 0.32992886
Q(16-2)=           8.6765.  Significance Level 0.85119919
Q(24-2)=          19.6654.  Significance Level 0.60396045
Q(32-2)=          23.7019.  Significance Level 0.78534082
Q(40-2)=          31.5922.  Significance Level 0.75905383
Q(48-2)=          41.1656.  Significance Level 0.67459695
```

(G1)

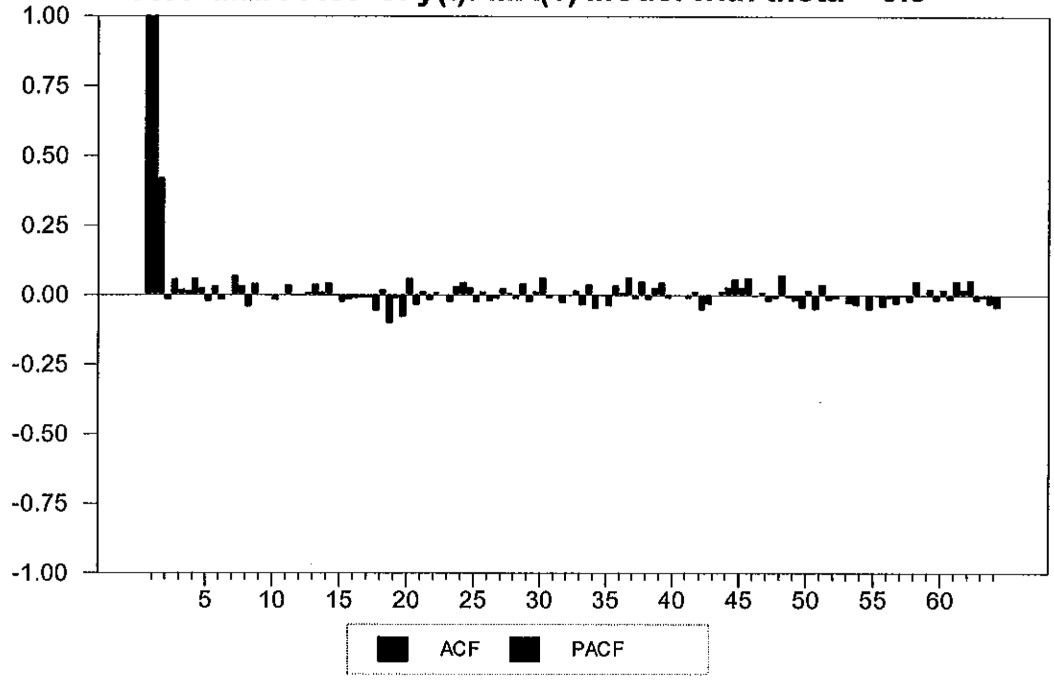

1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
5
10
15
20
25
30
35
40
45
50
55
60
ACF
PACF

(G2)


ACF of y(t): AR(1) Model with alpha = 0.99
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
5
10
15
20
25
30
35
40
45
50
55
60
ACF
PACF

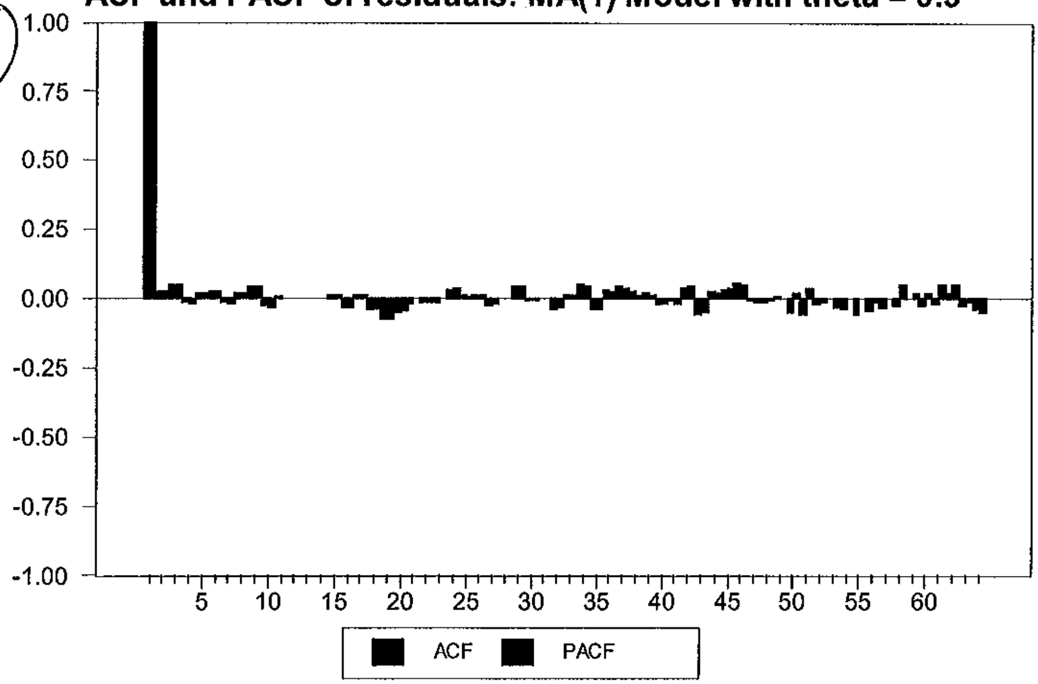
(G3)

ACF and PACF of y(t): MA(1) Model with theta = 0.5



(G4)

ACF and PACF of residuals: MA(1) Model with theta = 0.5



A

```
* ARMA_simulation_hw.PRG
* Box Jenkins Procedures

* Reading the data and plot
all 1000
open data arma_simulation.dat
data(format=prn,org=obs) / Y1 y2 y3 y4

set y = y3

statistics y

graph 1
# y

* Checking ACFs and plot
cor(partial=pacf, qstats) y / ACF
   * Modify the next line  ** No differencing will be made.

source(noecho) bjident.src
@bjident y


* Estimating an AR(1) model
boxjenk(constant, ar=1) y / resids

* Checking residuals
cor(partial=pacf,qstats,number=24,span=8,dfc=%nreg) resids / ACF

* AIC and BIC
compute aic = log(%rss/%nobs) + 2*(%nreg)/(%nobs)
compute BIC = log(%rss/%nobs) + %nreg*log(%nobs)/(%nobs)
display 'AIC = ' aic      '  BIC = ' BIC

* Estimating an AR(2) model
boxjenk(constant, ar=2) y / resids

* Checking residuals
cor(partial=pacf,qstats,number=24,span=8,dfc=%nreg) resids / ACF

* AIC and BIC
compute aic = log(%rss/%nobs) + 2*(%nreg)/(%nobs)
compute BIC = log(%rss/%nobs) + %nreg*log(%nobs)/(%nobs)
display 'AIC = ' aic      '  BIC = ' BIC

* Estimating an ma(1) model
boxjenk(constant, ma=1) y / resids

* Checking residuals
cor(partial=pacf,qstats,number=24,span=8,dfc=%nreg) resids / ACF

* AIC and BIC
compute aic = log(%rss/%nobs) + 2*(%nreg)/(%nobs)
compute BIC = log(%rss/%nobs) + %nreg*log(%nobs)/(%nobs)
display 'AIC = ' aic      '  BIC = ' BIC

* Estimating an MA(2) model
boxjenk(constant, ma=2) y / resids

* Checking residuals
cor(partial=pacf,qstats,number=24,span=8,dfc=%nreg) resids / ACF

* AIC and BIC
compute aic = log(%rss/%nobs) + 2*(%nreg)/(%nobs)
compute BIC = log(%rss/%nobs) + %nreg*log(%nobs)/(%nobs)
display 'AIC = ' aic      '  BIC = ' BIC
```

```
* Estimating ARMA(0,1) model
boxjenk(noprint,ar=0,ma=1, constant) y
compute aic = log(%rss/%nobs) + 2*(%nreg)/(%nobs)
compute BIC = log(%rss/%nobs) + %nreg*log(%nobs)/(%nobs)
display 'AIC = ' aic     '  BIC = ' BIC

* Re-estimating ARMA(1,1) model, while definfing it as eq1 for forecasting
boxjenk(define=eq1,constant,ar=1,ma=1) y / resids
compute aic = log(%rss/%nobs) + 2*(%nreg)/(%nobs)
compute BIC = log(%rss/%nobs) + %nreg*log(%nobs)/(%nobs)
display 'AIC = ' aic     '  BIC = ' BIC
  * Chekcing residuals
cor(partial=pacf,qstats,number=24,span=8,dfc=%nreg) resids / ACF

* The above forecasting can be done by using BJFORE.SRC
source(noecho) bjfore.src
@bjfore(ars=0,mas=1,constant) y 1001 1020 fores
print / fores

** Do-loop procedure
do i=0,5
do j=0,5
 boxjenk(ar=i,ma=j,constant,noprint) y
 compute aic = log(%rss/%nobs) + 2*(%nreg)/(%nobs)
 compute BIC = log(%rss/%nobs) + %nreg*log(%nobs)/(%nobs)
 display 'p ='  i  ' q =' j  '  AIC = ' aic     '  BIC = ' BIC
endo j
endo i

** Alternatively,
com BICmin = 100000000., BICp = 0, BICq = 0
do i=0,5
do j=0,5
 boxjenk(ar=i,ma=j,constant,noprint) y
 compute aic = log(%rss/%nobs) + 2*(%nreg)/(%nobs)
 compute BIC = log(%rss/%nobs) + %nreg*log(%nobs)/(%nobs)
 display 'p ='  i  ' q =' j  '  AIC = ' aic     '  BIC = ' BIC
 if BIC < BICmin
 {
  compute BICp = i
  compute BICq = j
  compute BICmin = BIC
  }
endo j
endo i
disp
disp 'Selected values of p and q using BIC = ' BICp  BICq
disp

* Now, Re-Estimating the ARMA(1,0) model
boxjenk(define=eq2,ar=1,ma=0, constant) y / resids
compute BIC = log(%rss/%nobs) + %nreg*log(%nobs)/(%nobs)
display '  BIC = ' BIC

* Chekcing residuals
cor(partial=pacf,qstats,number=24,span=8,dfc=%nreg) resids / ACF

* Forecasting 1-15 values starting from the 101th observation and save it
forecast(print) 1 15 1001 1015
# eq2 y_for

smpl 1 1015
graph(style=line) 2
# y
# y_for
```

Basics of RATS

1 Read data

This part is tricky [1]. For user of RATS 6.0 or above, the easiest way to define calendar and read data is to use Calendar and Data wizards, which are available under the Wizards menu. For old–version user, you need to do them manually. *It's a good idea to first read your data in Excel, and then re-save it as a xls file.* This step can preclude a lot of problems of reading data.

You should be reminded that in most cases, the calendar specification is not essential to how RATS handles your data. We can just skip them. It suffices to tell RATS how many observations you have in your sample. Then you need to specify the location of the data file, and its format.

For example, I have an excel file saved at my X drive, whose name is `Book1.xls`. By scanning the file in Excel, I know I have 145 observations (excluding the first row of variables names). The RATS commands to read the data are

```
OPEN DATA "X:\Book1.xls"
ALL 145
DATA(FORMAT=XLS,ORG=COLUMNS) 1 145 Cap Exports Govt GDP
```

or equivalently

```
DATA(FORMAT=XLS,ORG=COLUMNS) / Cap Exports Govt GDP
```

The variables of interest are `Cap Exports Govt GDP`, and we should list them *exactly the same way* as they appear in the first row of excel file. Note RATS is not case–sensitive. A common problem is RATS fails to read the file. When it occurs, you need to check if you've correctly specified the directory, or if the variable name is invalid (for instance, name is invalid if there is blank or symbol such as & in the name). RATS supports various formats, like `prn,xls,rat` and `dat`.

After reading the data, RATS automatically gives an entry number (or date if `Calender` is used before `Data` command) to each observation. If you are serious about the date, you can use set of commands as follows to read data

[1] prepared by Jing Li, Department of Economics, University of Alabama

```
calendar 1980 1 12
all 145
OPEN DATA "X:\Book1.xls"
DATA(FORMAT=XLS,ORG=COLUMNS) / Cap Exports Govt GDP
```

In this case, my first observation is January,1980. It's monthly data. If you have daily, weekly or quarterly data use commands (the starting dates are Jan 1, 1980; Jan 1, 1980 and first quarter of 1980 respectively.)

```
calendar(daily) 1980 1 1
calendar(sevenday) 1980 1 1
calendar 1980 1 4
```

2 Verify you data

Before serious analysis, we need to make sure data is properly read in. Try the two commands

```
table
print
```

The first one statistically summarizes variables in the memory. Please pay attention to statistics such as obs and maximum/minimum values. The second one displays the data on the screen. *Many difficulties can be avoided if you double-check your data beforehand.*

3 Data transformation

Transformations such as taking log or taking difference are common in time-series analysis. If we want to get the difference of log of GDP, use the command

```
set gdpd = log(gdp)-log(gdp{1}),
```

where gdp{1} gives you gdp_{t-1}. Similarly gdp{3} gives you gdp_{t-3}. **CAUTION** there are two blanks before and after the equality sign " $=$ ". After transforming data, type

```
print / gdpd
```

to verify it. Notice that missing values are generated when we difference data. If you want to generate a linear trend, a squared trend and a exponential trend series, use commands

```
set trend = t
set trendsq = t**2
set exptrend = exp(0.05*t)
```

Dummy variables are easy to generated using logical and relational operators. For example, if we want to construct a dummy which equals one if DGP is greater than 500, we can type

```
set dummy = gdp>500
```

Dr Lee may use commands such as `log` or `diff` to make the same transformation. The command `set` is more general and flexible.

4 Graph your data

For example, if I want to look at the time-plot of series `GDP`, I can type

```
graph(key=upleft, head='time series of GDP', subhead='this is nonsense')
1
# gdp
```

If I want to look at the X–Y scatter plots of series `GDP` and `GOVT`, type

```
scatter(vlabel='GOVT', hlable='GDP', head='GDP vs.GOVT') 1
# gdp govt
```

Graph Wizard is available in RATS 6.0.

5 Estimation and inference

You should be familiar with this part. I list three commands without interpreting them

```
linreg govt / resid
# constant gdp
test
# 2
# 0
prj fitted
```