Private information in inflation-indexed government bonds

By Peter B. Meyer, for Finance E20, Prof. Torben Andersen , June 18, 1998 update

Introduction

Corporate finance theories often carefully distinguish the information set of the decisionmaker from the information set of the capital markets. For example, the decision by a firm to sell new bonds is taken as a signal of the firm's future prospects. This separation is not usually discussed in the context of monetary and fiscal policy, institutions, and decisionmakers although in principle many of the same conditions exist. This paper attempts to show private information is signaled by the decision of a national government to issue inflation-indexed bonds.

Such a finding could be useful: (1) to improve forecasts of inflation; (2) to illuminate the structural interests in government decisionmaking; and (3) to partly explain why industrialized country governments have been so slow to issue indexed bonds, despite the overwhelming support of economists from J.M. Keynes to Milton Friedman. That explanation might be that the government sells indexed bonds only when it has a certain kind of information, or that private investors are unwilling to buy from a privately informed seller except when inflation is low.

Two types of government bonds

National governments of industrialized countries borrow principally by issuing bonds issued in their own currencies. Interest rates on the bonds are set in nominal terms and the values of the payments over time fluctuate with interest rates, inflation, and other factors. Buyers of these nominal bonds face an implicit risk that inflation may rise unexpectedly so as to reduce the value of the debt held by bondholders. This is one version of seignorage. Since those buyers are investing in a low-risk, low-return security one might expect them to be interested in lowering its risk further. A government bond whose payments were indexed to inflation would give them that.

An indexed bond contract has the problem which is the mirror image of seignorage -- that there could be an unexpected decline in inflation. If government bond issuers wanted to maximize real revenue, they could use hidden information about inflation or exercise inflation controls to manipulate the value of the bonds after sale.

Perhaps the example of such incentives that is easiest to understand is the following. Imagine that the managers of the department of the government responsible for issuing bonds have an interest in keeping real government debt low (e.g. to look good to their superiors and the public), and private, unverifiable (that is, uncontractible) information that inflation is about to rise. From their point of view this would be a poor time to issue inflation-indexed bonds since they would expect then to be paying higher bond interest payments than if they issued the usual nominal bonds. This case alone introduces a kind of adverse selection from the point of view of investors considering new bond issues; few bargains will appear and there is the increased possibility of a lemon.

Effects of and hypotheses about indexed bonds

Many effects of a government's decision to issue indexed bonds have been discussed in previous literature.

(1) They make it possible for investors buying domestic securities to reduce risk, not only by investing in a security without inflation risk itself, but by diversification: there is a negative correlation between inflation and returns on other investments (e.g. Munnell, p 8), but not with indexed bonds. Investors could buy bonds of other countries but we observe they don't much. Rather than model that, let's just assume they don't for some exogenous reason.

(2) Such bonds reduce borrowing cost for the government since it gets a premium for the implicit insurance against inflation risk.

(3) Their presence might lower the overall volume of government bond trading because investors wouldn't have to hedge against major interest rate swings. (Forbes, 1996 and Norton, 1996). That suggests that their introduction would bring about a rise in efficiency.

(4) The presence of both kinds of bonds gives policymakers a useful market measure of expected inflation. (Shen, Hetzel). The difference between the expected nominal rates of return on the indexed and non-indexed bonds, called the yield gap, is a market measure of expected inflation. Woodward (1990) measures this. That measure can be used by policymakers to read financial market expectations of inflation, which gives them feedback on the effects of policy.

(5) Their presence reduces the incentive for the government to inflate to get seigniorage revenues.

Economists have advocated indexed bonds for a long time. Hetzel, p. 13, cites J.M. Keynes in 1924, and Milton Friedman in 1951, as having done so. Recent examples include Shen (1995). Still it took until 1997 before the U.S. issued these bonds.

Given those advantages why haven't they been offered more by industrialized countries? Conjectures:

(1) Finance theorists have argued that the issue of indexed bonds is of minimal welfare value because the possible buyers are well protected against inflation anyway (Viard, 1993, D Lucas). This is the only one of the possible explanations listed here which to the author's knowledge has been formally modeled or subjected to published econometric study.

(2) Private bond dealers prefer volatile products because there is more trading and thus more commissions. Those bond dealers would expect to lose business to the less-volatile indexed bonds market, and might pressure governments not to offer them.

(3) The new issue would split the market for government bonds into categories. If the submarkets were too small or illiquid the net efficiency effect of the new issue might be negative.

(4) It has been hypothesized that there was a general lack of demand for the new bonds; that is that private interests U.S. investors did not request them. (Hetzel, p 7; Munnell and Grolnick p 4; D. Lucas).

(5) There has been concern about the credibility of the government finance department (e.g., the U.S. Treasury). Sometimes this is described as the organization's cultural preference not to debt-manage. One reason for this general preference could be that the government finance department's employees, who would like to issue stable and predictable securities, have a long term structural conflict with each new generation of political appointees who might want to lower interest payments at all costs. (Hetzel p. 14)

(6) Asymmetric information in the short run, either (a) adverse selection, or (b) moral hazard. These hypotheses have only barely been suggested elsewhere. This paper will try to detect these effects. Formally, the adverse selection conjecture is that government bond-issuers have private information about the future of inflation, and only those who have private reason to expect inflation to fall will issue the indexed type of bond. The moral hazard conjecture is that the behavior of government controls on inflation would change after the incentives of the government have changed by its issue of inflation-indexed bonds.

Possible models of asymmetric information

Models of this kind are common in the corporate finance literature (e.g. Myers and Majluf (1984)), where company managers have private information about a company's prospects and control over its decisions. Such models have not often been applied to governments although in principle many of the same issues exist: government officials need to look good to their constituents in order to be reelected or reappointed, and this private interest may pull them away from their best policy.

Model (A). The bond issuer has private information about future inflation that is not visible to the public, and this private information affects whether it offers indexed bonds or not. This is an adverse selection model, and probably the most convincing of the three here. To formalize it, imagine a model in which the government bond issuers every period knows in advance whether there will be high inflation, characterized by mean μ_{high} and variance σ_{high}, or low inflation, characterized by mean μ_{low} and variance σ_{low}. Assume also that the public does not know this. Then the government bond issuers could avoid beginning the indexed bond regime before a high inflation period, which would impose high nominal bond payment costs. Instead it could choose to release such bonds just before a low inflation period. This primitive model predicts that an inflation-indexed bond issue will Granger-cause a decline in inflation.

Model (B). The government's incentives in inflation choice change after it issues bonds that are indexed to inflation. The bond-issuing agency could collude with the monetary authority in order to reduce borrowing costs. This is a moral hazard faced by the bond buyers since their return would be lower in real terms than if the government did not have the new incentive. Using the notation of model (A), imagine that the government agency with the best control on inflation (say, the central bank) were in alliance with the bond-issuing agency. Then after the issuance of indexed bonds the central bank, in choosing to exercise its control over whether there would be high inflation, could take into account the bond issuing agency’s preference for low bond payments and therefore inflation.

Model (C). The bond-issuing agency could collude with the government's statistics agency that makes the official measure of the inflation rate. (In the United States that is the Bureau of Labor Statistics, or BLS.) A revenue-maximizing bond-issuing agency has an incentive to misreport the official measure of inflation and thus pay less in bond interest. Recent (1996-7) discussion of possible changes in the U.S. government's Consumer Price Index suggests some such hazard: most media discussion has not been about whether the changes would make the CPI a better measure but whether it would bring the government's budget closer to balance. The discussion has presumably not affected the recent U.S. inflation-indexed bond issue since the Treasury committed to using a known inflation measure for calculating interest payments on this particular bond but a structural conflict between institutions may have been observed when the BLS resisted proposed changes.

Methodology

Inflation-indexed bond contract terms vary greatly across countries. They index principal, or interest, or both, with various lags. Differences in how they are taxed are complicated, and the details are important to the buyers and therefore have a major impact on prices. The details will be left out in this paper. But this makes the pricing of indexed bonds hard to compare directly across countries. Pricing data will not be used in this paper. No assumption is made here about whether at the time the bonds were issued they were priced well in retrospect.

The study here is of whether government issues of indexed bonds Granger-cause a decline in inflation as it would under any of the private information conjectures above. To this end, AR-ARCH or AR-GARCH decompositions of the time series on inflation data in the U.K., Australia, Canada, and Sweden will be calculated, and then a binary regressor for whether inflation-indexed bonds have been issued will be added to the regression. If it has explanatory power, the issuance Granger-caused a change in inflation, and this will be taken as (weak) evidence that the inflation regime has changed.

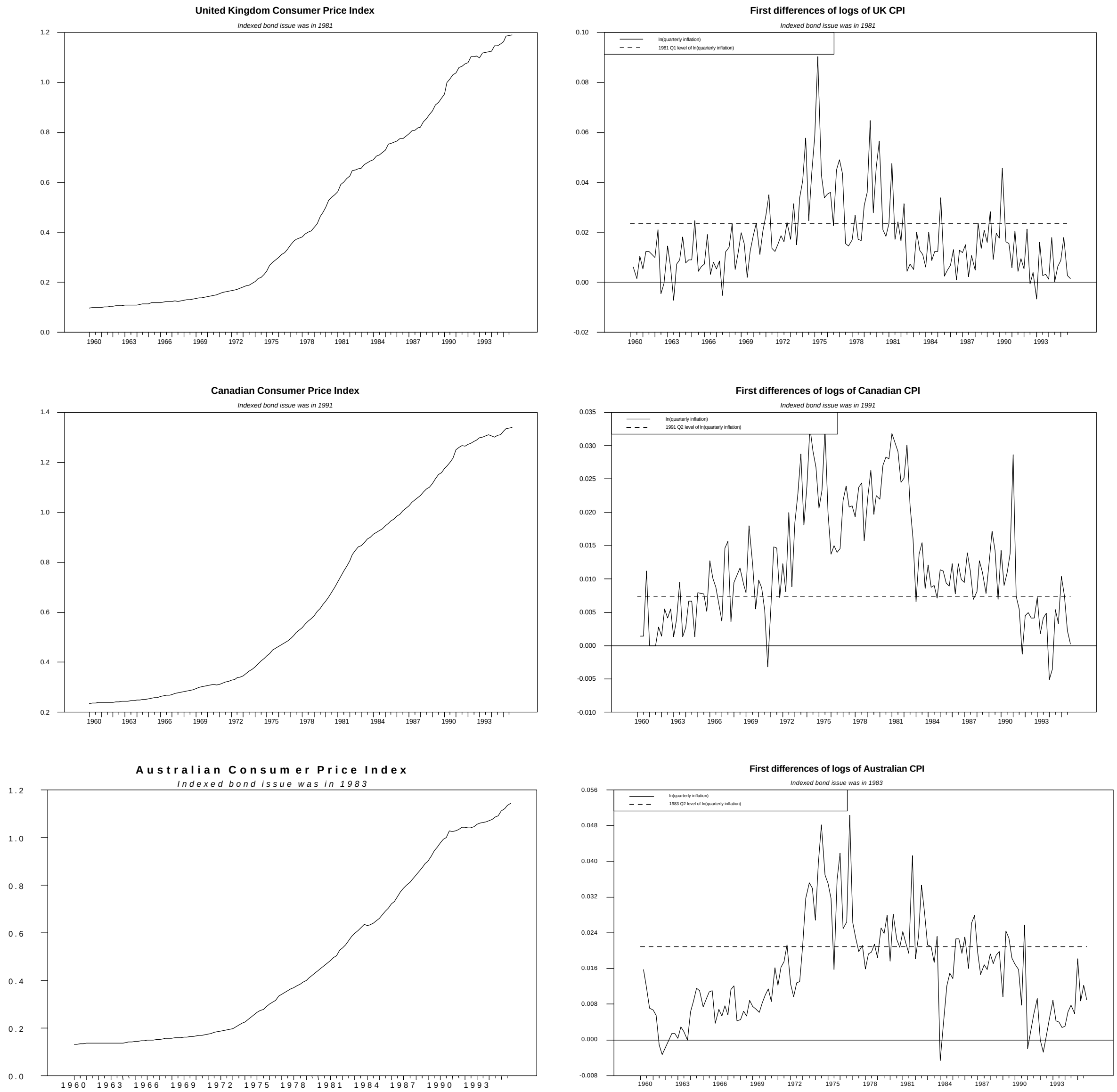
The classic paper Engle (1982) addressed the problem of modeling inflation time series directly with its introduction of the ARCH models. GARCH models like that of Bollerslev (1986) may fit better.

Engle (1982) experimented with models to fit the data on British inflation from 1958 to 1977, and arrived at this equation:

$$p_t=\beta_5+\beta_1 p_{t-1}+\beta_2 p_{t-4}+\beta_3 p_{t-5}+\beta_4(p_{t-1}-w_{t-1})$$

where p_t denotes first differences between logs of the quarterly consumer price index, the β's are coefficients to be estimated, and w_t was the log of the quarterly index of manual wage rates. The 1982 paper goes on to explore modeling the changing variance over time with the ARCH (autoregressive conditionally heteroskedastic) time series model which will be included here.

Cukierman (1992) has constructed an index of central bank independence from the political arm of the government. (See table in Appendix B.) Asymmetric information arguments suggest that this should be a good predictor of the government's choice to issue the bond. Interestingly, a look at Appendix B suggests it does not. It seems to me useful to think about why this would be. Another possible regressor is the type of the party in power at the time of the issue -- e.g., is it to the left of center of the political spectrum, or not.



The graphs above give intuitive confirmation of the theory. In each case it is visible in the graph on the right that the inflation rate is lower on average after the country issues indexed bonds than it was before. The dotted lines mark the approximate level of inflation in the quarter before the issue, at which time it is presumably common knowledge that the government intends to issue them, and any private information would be incorporated into the decision to issue. Looking at the graphs, however, does not take into account autoregression in the inflation process and autoregressive variance, or ARCH, effects. The basic intuition will, however, be confirmed (weakly) by the estimation methods below which do take these aspects of inflation into account.

The inflation series was defined, as in Engle's paper and the graphs above, by the first differences of the logs of the consumer price index of each country for each quarter. That is, the series was just logged inflation as conventionally defined, quarter by quarter.

An AR(5)-GARCH(1,1) time series model was fit to the inflation data series of each country. Specifically, using the same notation as above, the model applied was:

$$p_t=\beta_0+\beta_1 p_{t-1}+\beta_2 p_{t-2}+\beta_3 p_{t-3}+\beta_4 p_{t-4}+\beta_5 p_{t-5}+\varepsilon_t$$

$$\text{where} \quad \varepsilon_t \sim N(0,\sigma_t^2)$$

$$\text{and} \quad \sigma_t^2=\alpha_0+\alpha_1\varepsilon_{t-1}^2+\alpha_2\sigma_{t-1}^2$$

The α's and the β's are coefficients which are estimated by maximum likelihood methods. Necessary byproducts are sequences of the residual series $\{\varepsilon_t\}$and the conditional variance series $\{\sigma_t\}$which were examined for evidence of further autocorrelation and volatility (autocorrelated conditional variance).

Other models fit each series better, but the one was chosen as a compromise for all the series to make results more comparable. The same model, plus a new binary variable which is zero until the major indexed bond sale, then one afterward, was fit to the data. Those are the results reported here:

Country	Constant	AR(1)	AR(2)	AR(3)	AR(4)	AR(5)	Variance	ARCH(1)	GARCH(1)	**Indexed bonds dummy**
Australia	.002521	.4093	.2546	.2411	.0476	-.1209	.000089	0.1253	-0.9417	**-.0000876 (-1.003) [.316]**
Canada	.000102	.6612	-0.1282	.0322 (1.945) [.05176]	.5669	-.2091	.0000059	.1921	-0.8680	**-.0007689**
U.K.	.00456	.4412	.0815 (1.47) [.14]	-.1569	.6083	-0.3382	.0000166	0.6424	0.3422	**-.0000899 (-.686) [.493]**

In each case: N=137, and there were 127 degrees of freedom in the statistics.
T-statistics are reported in parentheses () and significance levels in square brackets [] for those coefficients which were not statistically significant at the .05 level.

The basic results are in the table above. The theories discussed earlier predict that the issue of indexed bonds will Granger-cause inflation to fall. In each of the above cases it does, but not usually to a degree that was statistically significant at the .05 or .10 level. So there is still a fair possibility that the results on that variable come from chance.

A few problems in estimation were noteworthy. The residuals from the estimation of the mean of the inflation series were not highly autocorrelated, but the Ljung-Box statistic strongly rejected the hypothesis that they were uncorrelated. Applied to the squares of the residuals, the Ljung-Box statistic strongly rejected the hypothesis that the residual variance was no longer autocorrelated. Thus the specification used here was not sufficient to remove either autocorrelation or volatility in any of the time series. More complicated ARMA-GARCH specifications were attempted to get around this problem but the maximum likelihood estimation did not converge for those specifications.

Also the GARCH coefficient is supposed to be positive in theory, since the variance of the process could otherwise be negative. This does not present a problem in estimation or forecasting here, but it suggests that the GARCH(1,1) specification is a problematic abstraction for the data considered; the statistical process as calibrated here could not be simulated infinitely because the conditional variance in a simulation would sometimes be negative.

Estimation of the inflation process by many models simpler than AR(5)-GARCH(1,1) was attempted. The same basic results were found for the variable of interest – the indexed bonds dummy's coefficient was negative, but not highly significant statistically.

U.S. data was not used for the estimation because the inflation-indexed bond issue because the January 1997 issue is too recent; only a year of data is available. But it has been commented for a few years now that U.S. inflation has been quiescent. Similar results hold for Sweden (I believe) which issued indexed bonds in 1994. Regardless of the structural cause of recent inflation quiescence in these countries, it confirms the basic intuition suggested here, that governments issue inflation-indexed bonds when they expect inflation to fall.

Conclusion

Econometric confirmation of the theories that the first issue of inflation-indexed bonds signals declining inflation to follow was indeed found, but it was weak statistically. Stronger evidence is possible with further research. U.S. and Swedish data will be suitable for such tests in a few years, but they have issued the bonds too recently for such results to be meaningful now in early 1998. A Chow test of structural change in the inflation process at the time of the bond issue might confirm the cause described here.

Appendix A

Ranking of central banks by an overall index of independence during the 1980s, shown in first column. Source: Table 21.1 from Cukierman.

	Index of legal independence	Depreciation of currency	independence of currency (LVAU)	
Denmark	.04	.05	.47	
W Germany	.05	.02	.66	
United States	.06	.04	.38	
Canada	.06	.05	.46	
Norway	.06	.07	.14	
Sweden	.07	.06	.27	
Britain	.07	.05	.31	
Australia	.08	.07	.31	
France	.09	.06	.28	
Hungary	.09	.07	.24	.10
Spain	.10	.08	.21	
New Zealand	.10	.08	.27	
Iceland	.11	.24	.36	
Greece	.11	.15	.51	.20
Thailand	.11	.04	.26	.10
Nigeria	.12	.16	.33	.10
Tanzania	.13	.2	.48	.20
Malta	.13	.02	.45	.20
Kenya	.13	.09	.44	.20
Philippines	.14	.11	.42	.20
Barbados	.14	.05	.40	.10
Nepal	.16	.08	.25	.10
Ghana	.16	.28	.28	.20
Bahamas	.16	.05	.45	.20
India	.17	.07	.33	.30
Zimbabwe	.18	.11	.23	.10
Egypt	.18	.13	.53	.30
Israel	.20	.47	.42	.20
Zaire	.20	.34	.41	.20
South Africa	.20	.12	.30	.20
Indonesia	.21	.07	.32	.20
Costa Rica	.23	.19	.42	.40
Nicaragua	.25	.67	.42	.40
South Korea	.25	.05	.23	.50
Uruguay	.26	.05	.28	.30
Western Samoa	.26	.05	.28	.56
Zambia	.26	.25	.31	.50
Ethiopia	.27	.04	.47	.10
Peru	.27	.64	.43	.30
Mexico	.28	.38	.36	.30
Venezuela	.28	.04	.37	.50
Turkey	.29	.28	.44	.40
Botswana	.30	.09	.36	.40
Chile	.35	.15	.49	.80
Brazil	.36	.68	.26	.80
Argentina	.39	.74	.44	1.00

The countries relevant to this paper are Australia, Canada, the United Kingdom, and Sweden and the United States have also issued indexed bonds. All have a high degree of political independence for the central bank, which suggests that their inflation is expected to be controllable. Central bank independence may predict which countries issue indexed bonds. Countries at the top of the list are in a strong position to do so. Countries at the bottom of the list have to, because private investors do not trust their currencies. Countries in the middle of the list (between Iceland and Mexico, with the exception of Israel) are observed not to issue indexed bonds.

Appendix B

Issues of inflation-indexed government bonds. Source: Deacon and Andrews, 1996, p. 16.

Country	Issue date	Index used	Comments
Argentina	1972	Non-agricultural wholesale prices	
Australia	1983	consumer prices	major (p 17)
	1991	average weekly earnings	major (p 17)
Austria	1953	electricity prices	
Brazil	1964-1980	wholesale prices	
Canada	1991	consumer prices	
Finland	1945-1967	wholesale prices	
France	1952, 1973	gold price	
	1956	level of industrial production	
	1956	average value of French securities	
	1957	price of equities	
Hungary	1996	consumer inflation	
Iceland	1955	consumer prices	
	1964-1979	Cost of Building index	
	1979-1995	Credit Terms index	
	1995	Consumer Price index	major (p 17)
Ireland	1983	Consumer prices	
Israel	1948-	Consumer prices	2^{nd} largest market
Italy	1983	GDP prices at factor cost	
Mexico	1989	Consumer prices	
New Zealand	1979-1984	'All Groups' consumer prices	
New Zealand	1995-	'All Groups' consumer prices	
Poland	1992-	consumer goods and service prices	
Sweden	1952	Consumer prices	"major" per page 17
	1994	Consumer prices	
U.K.	1975-?		
	1981-	Retail prices	"major"; largest market in world
U.S. state of Massachusetts	1742		
U.S.	1997	Consumer prices	

Only a few of these issues are considered in the paper. Only OECD countries were considered to avoid the driving force for inflation-indexed issues by less-developed countries, which is that their nominal issues are not trusted.

Econometrics were run only on Canadian, British, and Australian data.

Appendix C: Data and computing background

The dependent variables in this study are these series of quarterly CPI deflators used in estimation, going from the beginning of 1960 to the end of 1995.

The inflation data come from OECD economist Tito Boeri (Tito.Boeri@oecd.org).

Estimation of the ARCH models was done by Gauss's MAXLIK procedure, version 4.0.26 on a Hewlett Packard Unix computer, and in RATS version 4.31 on a PC. Where comparable results were obtained in both programs the results did agree. This partially confirms of the correctness of the programs used.

Appendix D: Computer programs and results

Below are the RATS computer program and its output. These are the final results discussed in the paper.

```
;*  This program runs ARCH and informational statistical models
;*  on inflation rates.   Peter B Meyer  3/18/98

calendar 1960 1 4
allocate 0 1995:4          ;* data runs until 1995:Q4
open data fewprice.prn
data(format=prn,org=obs)
table

;*  Now GARCH estimation of the Australian data

display '****************************************************'
display '****************  Australian data  ****************'
display '****************************************************'
display 'Now running GARCH on the Australian inflation data'
set dlcpi = log(austral) - log(austral{1})

set w = 0.0             ;* this creates a time series of disturbances
set u = 0.0
nonlin b0 b1 b2 b3 b4 b5 a0 a1 a2  ;* these will be estimated
;* b0 is const, b1 is AR(1), b2 is AR(2), b3 is AR(3), b4 is AR(4), etc,
;* a0 is var0, a1 is ARCH term, a2 is GARCH term

frml e = dlcpi-b0-b1*dlcpi{1}- $
         b2*dlcpi{2}-b3*dlcpi{3}-b4*dlcpi{4}-b5*dlcpi{5}
frml var = a0+a1*e{1}**2+a2*w{1}            ;* last is GARCH term
frml L = (u = e), (w = var), -.5*(log(var)+e(t)**2/var)

;*  Next three lines initialize starting point for max likelihood
;* insert 'noprint' back in the line below, later
boxjenk(constant,ar=5,iter=975) dlcpi
compute b0=%beta(1),b1=%beta(2),b2=%beta(3),b3=%beta(4),b4=%beta(5)
compute b5=%beta(5)
compute a0=.001, a1=.087, a2=.4

;* nlpar(subiterations=150)
maximize(iterations=75) L 8 *
compute b0=%beta(1),b1=%beta(2),b2=%beta(3),b3=%beta(4),b4=%beta(5)
compute b5=%beta(6)
compute a0=%beta(7), a1=%beta(8), a2=%beta(9)

set resids = 0.0
set resids 61:3 95:4 = dlcpi-b0-b1*dlcpi{1}-b2*dlcpi{2} $
                               -b3*dlcpi{3}-b4*dlcpi{4}-b5*dlcpi{5}
;*  examine the output from the below to find no
;*  remaining autocorr in the disturbances
cor(qstats,dfc=%nreg,number=12,span=8) resids 61:3 95:4

;*  likewise check for any remaining volatility in the residuals
display 'Below are tests for volatility in residuals'
set ressq = resids*resids     ;* Form the squared residuals
cor(partial=pacf,qstats,number=12,span=4,dfc=%nreg) ressq
linreg ressq        ;* run Lagrange multiplier test for ARCH(4) errors
# constant ressq{1 to 4}


display 'Now running GARCH with iib flag on the Australian inflation data'
set ausiib = t>1983:1   ;* Australian inflation-indexed bonds exist y/n flag

set w = 0.0             ;* this creates a time series of disturbances
set u = 0.0
nonlin b0 b1 b2 b3 b4 b5 a0 a1 a2 c0  ;* these will be estimated
;* b0 is const, b1 is AR(1), b2 is AR(2), b3 is AR(3), b4 is AR(4), etc,
;* a0 is var0, a1 is ARCH term, a2 is GARCH term

frml e = dlcpi-b0-b1*dlcpi{1}- $
         b2*dlcpi{2}-b3*dlcpi{3}-b4*dlcpi{4}-b5*dlcpi{5}-c0*ausiib
frml var = a0+a1*e{1}**2+a2*w{1}            ;* last is GARCH term
frml L = (u = e), (w = var), -.5*(log(var)+e(t)**2/var)

;*  Previous MLE initialized starting point for this one
compute c0 = -.0008    ;* except for c0

nlpar(subiterations=35)
maximize(iterations=75) L 8 *
compute b0=%beta(1),b1=%beta(2),b2=%beta(3),b3=%beta(4),b4=%beta(5)
compute b5=%beta(6)
compute a0=%beta(7), a1=%beta(8), a2=%beta(9), c0=%beta(10)

set resids = 0.0
set resids 61:3 95:4 = dlcpi-b0-b1*dlcpi{1}-b2*dlcpi{2} $
                               -b3*dlcpi{3}-b4*dlcpi{4}-b5*dlcpi{5}-c0*ausiib
;*  examine the output from the below to find no
;*  remaining autocorr in the disturbances
cor(qstats,dfc=%nreg,number=12,span=8) resids 61:3 95:4

;*  likewise check for any remaining volatility in the residuals
display 'Below are tests for volatility in residuals'
set ressq = resids*resids     ;* Form the squared residuals
cor(partial=pacf,qstats,number=12,span=4,dfc=%nreg) ressq
linreg ressq        ;* run Lagrange multiplier test for ARCH(4) errors
# constant ressq{1 to 4}



;*  Now GARCH estimation of the Canadian data

display '****************************************************'
display '****************  Canadian data  ****************'
display '****************************************************'
display 'Now running GARCH on the Canadian inflation data'
set dlcpi = log(canada) - log(canada{1})

set w = 0.0             ;* this creates a time series of disturbances
set u = 0.0
nonlin b0 b1 b2 b3 b4 b5 a0 a1 a2  ;* these will be estimated
;* b0 is const, b1 is AR(1), b2 is AR(2), b3 is AR(3), b4 is AR(4), etc,
;* a0 is var0, a1 is ARCH term, a2 is GARCH term

frml e = dlcpi-b0-b1*dlcpi{1}- $
         b2*dlcpi{2}-b3*dlcpi{3}-b4*dlcpi{4}-b5*dlcpi{5}
frml var = a0+a1*e{1}**2+a2*w{1}            ;* last is GARCH term
frml L = (u = e), (w = var), -.5*(log(var)+e(t)**2/var)

;*  Next three lines initialize starting point for max likelihood
;* insert 'noprint' back in the line below, later
boxjenk(constant,ar=5,iter=975) dlcpi
compute b0=%beta(1),b1=%beta(2),b2=%beta(3),b3=%beta(4),b4=%beta(5)
compute b5=%beta(5)
compute a0=.001, a1=.1, a2=-.8

nlpar(subiterations=35)
maximize(iterations=175) L 8 *
compute b0=%beta(1),b1=%beta(2),b2=%beta(3),b3=%beta(4),b4=%beta(5)
compute b5=%beta(6)
compute a0=%beta(7), a1=%beta(8), a2=%beta(9)

set resids = 0.0
set resids 61:3 95:4 = dlcpi-b0-b1*dlcpi{1}-b2*dlcpi{2} $
                               -b3*dlcpi{3}-b4*dlcpi{4}-b5*dlcpi{5}
;*  examine the output from the below to find no
;*  remaining autocorr in the disturbances
cor(qstats,dfc=%nreg,number=12,span=8) resids 61:3 95:4

;*  likewise check for any remaining volatility in the residuals
display 'Below are tests for volatility in residuals'
set ressq = resids*resids     ;* Form the squared residuals
cor(partial=pacf,qstats,number=12,span=4,dfc=%nreg) ressq
linreg ressq        ;* run Lagrange multiplier test for ARCH(4) errors
# constant ressq{1 to 4}


display 'Now running GARCH with iib flag on the Canadian inflation data'
set caniib = t>1991:1   ;* Canadian inflation-indexed bonds exist y/n flag

set w = 0.0             ;* this creates a time series of disturbances
set u = 0.0
nonlin b0 b1 b2 b3 b4 b5 a0 a1 a2 c0  ;* these will be estimated
;* b0 is const, b1 is AR(1), b2 is AR(2), b3 is AR(3), b4 is AR(4), etc,
;* a0 is var0, a1 is ARCH term, a2 is GARCH term
```

```
frml e = dlcpi-b0-b1*dlcpi{1}- $
         b2*dlcpi{2}-b3*dlcpi{3}-b4*dlcpi{4}-b5*dlcpi{5}-c0*caniib
frml var = a0+a1*e{1}**2+a2*w{1}            ;* last is GARCH term
frml L = (u = e), (w = var), -.5*(log(var)+e(t)**2/var)

;*  Previous MLE initialized starting point for this one
compute c0 = -.01    ;* except for c0

;* nlpar(subiterations=150)
maximize(iterations=975) L 8 *
compute b0=%beta(1),b1=%beta(2),b2=%beta(3),b3=%beta(4),b4=%beta(5)
compute b5=%beta(6)
compute a0=%beta(7), a1=%beta(8), a2=%beta(9), c0=%beta(10)

set resids = 0.0
set resids 61:3 95:4 = dlcpi-b0-b1*dlcpi{1}-b2*dlcpi{2} $
                               -b3*dlcpi{3}-b4*dlcpi{4}-b5*dlcpi{5}-c0*caniib
;*  examine the output from the below to find no
;*  remaining autocorr in the disturbances
cor(qstats,dfc=%nreg,number=12,span=8) resids 61:3 95:4

;*  likewise check for any remaining volatility in the residuals
display 'Below are tests for volatility in residuals'
set ressq = resids*resids     ;* Form the squared residuals
cor(partial=pacf,qstats,number=12,span=4,dfc=%nreg) ressq
linreg ressq        ;* run Lagrange multiplier test for ARCH(4) errors
# constant ressq{1 to 4}




;*  Now GARCH estimation of the British data

display '**************************************************'
display '***************  British data  ***************'
display '**************************************************'
display 'Now running GARCH on the British inflation data'
set dlcpi = log(uk) - log(uk{1})

set w = 0.0             ;* this creates a time series of disturbances
set u = 0.0
nonlin b0 b1 b2 b3 b4 b5 a0 a1 a2  ;* these will be estimated
;* b0 is const, b1 is AR(1), b2 is AR(2), b3 is AR(3), b4 is AR(4), etc,
;* a0 is var0, a1 is ARCH term, a2 is GARCH term

frml e = dlcpi-b0-b1*dlcpi{1}- $
         b2*dlcpi{2}-b3*dlcpi{3}-b4*dlcpi{4}-b5*dlcpi{5}
frml var = a0+a1*e{1}**2+a2*w{1}           ;* last is GARCH term
frml L = (u = e), (w = var), -.5*(log(var)+e(t)**2/var)

;*  Next three lines initialize starting point for max likelihood
;* insert 'noprint' back in the line below, later
boxjenk(constant,ar=5,iter=975) dlcpi
compute b0=%beta(1),b1=%beta(2),b2=%beta(3),b3=%beta(4),b4=%beta(5)
compute b5=%beta(5)
compute a0=.001, a1=.087, a2=.4

;* nlpar(subiterations=150)
maximize(iterations=75) L 8 *
compute b0=%beta(1),b1=%beta(2),b2=%beta(3),b3=%beta(4),b4=%beta(5)
compute b5=%beta(6)
compute a0=%beta(7), a1=%beta(8), a2=%beta(9)

set resids = 0.0
set resids 61:3 95:4 = dlcpi-b0-b1*dlcpi{1}-b2*dlcpi{2} $
                               -b3*dlcpi{3}-b4*dlcpi{4}-b5*dlcpi{5}
;*  examine the output from the below to find no
;*  remaining autocorr in the disturbances
cor(qstats,dfc=%nreg,number=12,span=8) resids 61:3 95:4

;*  likewise check for any remaining volatility in the residuals
display 'Below are tests for volatility in residuals'
set ressq = resids*resids     ;* Form the squared residuals
cor(partial=pacf,qstats,number=12,span=4,dfc=%nreg) ressq
linreg ressq        ;* run Lagrange multiplier test for ARCH(4) errors
# constant ressq{1 to 4}


display 'Now running GARCH with iib flag on the British inflation data'
set ukiib = t>1981:1   ;* British inflation-indexed bonds exist y/n flag

set w = 0.0             ;* this creates a time series of disturbances
set u = 0.0
nonlin b0 b1 b2 b3 b4 b5 a0 a1 a2 c0  ;* these will be estimated
;* b0 is const, b1 is AR(1), b2 is AR(2), b3 is AR(3), b4 is AR(4), etc,
;* a0 is var0, a1 is ARCH term, a2 is GARCH term

frml e = dlcpi-b0-b1*dlcpi{1}- $
         b2*dlcpi{2}-b3*dlcpi{3}-b4*dlcpi{4}-b5*dlcpi{5}-c0*ukiib
frml var = a0+a1*e{1}**2+a2*w{1}           ;* last is GARCH term
frml L = (u = e), (w = var), -.5*(log(var)+e(t)**2/var)

;*  Previous MLE initialized starting point for this one
compute c0 = -.01    ;* except for c0

;* nlpar(subiterations=150)
maximize(iterations=75) L 8 *
compute b0=%beta(1),b1=%beta(2),b2=%beta(3),b3=%beta(4),b4=%beta(5)
compute b5=%beta(6)
compute a0=%beta(7), a1=%beta(8), a2=%beta(9), c0=%beta(10)

set resids = 0.0
set resids 61:3 95:4 = dlcpi-b0-b1*dlcpi{1}-b2*dlcpi{2} $
                               -b3*dlcpi{3}-b4*dlcpi{4}-b5*dlcpi{5}-c0*ukiib
;*  examine the output from the below to find no
;*  remaining autocorr in the disturbances
cor(qstats,dfc=%nreg,number=12,span=8) resids 61:3 95:4

;*  likewise check for any remaining volatility in the residuals
display 'Below are tests for volatility in residuals'
set ressq = resids*resids     ;* Form the squared residuals
cor(partial=pacf,qstats,number=12,span=4,dfc=%nreg) ressq
linreg ressq        ;* run Lagrange multiplier test for ARCH(4) errors
# constant ressq{1 to 4}

display '**************************************************'
display '********************  Done  ********************'
display '**************************************************'



;*  That ends the program.  Here is the output of that program:
```

```
Series            Obs       Mean        Std Error      Minimum       Maximum
AUSTRAL            144 0.48187804167 0.34497434442 0.13086600000 1.14563000000
CANADA             144 0.66376050000 0.39126055080 0.23556900000 1.33878000000
UK                 144 0.49120405486 0.37107127358 0.09794890000 1.19009000000
ICELAND            144 0.29597992708 0.42677132813 0.00103913000 1.20294000000
SWEDEN             144 0.46593934722 0.33038628467 0.12224500000 1.12938000000
```

```
**************************************************
***************  Australian data  ***************
**************************************************
Now running GARCH on the Australian inflation data

Dependent Variable DLCPI - Estimation by Box-Jenkins
Iterations Taken     3
Quarterly Data From 1961:03 To 1995:04
Usable Observations    138      Degrees of Freedom   132
Centered R**2     0.644911      R Bar **2   0.631461
Uncentered R**2   0.878839      T x R**2     121.280
Mean of Dependent Variable      0.0153806189
Std Error of Dependent Variable 0.0111094560
Standard Error of Estimate      0.0067442627
Sum of Squared Residuals        0.0060040305
Durbin-Watson Statistic             1.983627
Q(34-5)                            37.253907
Significance Level of Q           0.13984049

   Variable                     Coeff       Std Error      T-Step     Signif
*******************************************************************************
1.  CONSTANT                  0.015754758  0.004338398      3.63147  0.00040208
2.  AR{1}                     0.439603593  0.086582464      5.07728  0.00000128
3.  AR{2}                     0.152459872  0.094451455      1.61416  0.10888046
4.  AR{3}                     0.283680659  0.092083630      3.08069  0.00251382
5.  AR{4}                     0.098013662  0.095542958      1.02586  0.30683402
6.  AR{5}                    -0.106233498  0.087149193     -1.21898  0.22502406


Estimation by BFGS
Iterations Taken    27
Quarterly Data From 1961:04 To 1995:04
Usable Observations    137      Degrees of Freedom   128
Function Value                    626.33010938

   Variable                     Coeff       Std Error      T-Stat     Signif
*******************************************************************************
1.  B0                        1.8514e-003  9.6015e-004      1.92822  0.05382726
2.  B1                             0.4290       0.0548      7.82408  0.00000000
3.  B2                             0.2174       0.0426      5.10155  0.00000034
4.  B3                             0.2719       0.0000      0.00000  0.00000000
5.  B4                             0.0564       0.0834      0.67629  0.49885427
6.  B5                            -0.1218       0.0726     -1.67862  0.09322529
7.  A0                        8.0994e-005  6.4212e-006     12.61364  0.00000000
8.  A1                             0.1071       0.0177      6.03878  0.00000000
9.  A2                            -0.9486       0.0287    -33.01641  0.00000000

Correlations of Series RESIDS
Quarterly Data From 1961:03 To 1995:04
Autocorrelations
     1:  0.0135522 -0.0886292 -0.0236286  0.0291791 -0.0210017  0.0789726
     7: -0.1661414  0.0905499 -0.0341194 -0.0036021  0.0386581  0.0841418


Ljung-Box Q-Statistics
Q(8)   =          7.6108.  Significance Level 0.00000000

Below are tests for volatility in residuals
Correlations of Series RESSQ
Quarterly Data From 1960:01 To 1995:04
Autocorrelations
     1:  0.1971528 -0.0228763  0.0806153  0.0549344  0.1323951  0.0894141
     7: -0.0302316  0.0290821  0.2905467  0.0635596 -0.0086924 -0.0422171

Partial Autocorrelations
     1:  0.1971528 -0.0642426  0.1024701  0.0161812  0.1335696  0.0334668
     7: -0.0482172  0.0328312  0.2754689 -0.0658168  0.0076199 -0.0922956


Ljung-Box Q-Statistics
Q(4)   =          7.2143.  Significance Level 0.00000000
Q(8)   =         11.3545.  Significance Level 0.00000000
Q(12)  =         25.4307.  Significance Level 0.00001255


Dependent Variable RESSQ - Estimation by Least Squares
Quarterly Data From 1961:01 To 1995:04
Usable Observations    140      Degrees of Freedom   135
Centered R**2     0.051744      R Bar **2   0.023648
Uncentered R**2   0.240426      T x R**2      33.660
Mean of Dependent Variable      0.0000433415
Std Error of Dependent Variable 0.0000872733
Standard Error of Estimate      0.0000862352
Sum of Squared Residuals        0.0000010039
Regression F(4,135)                   1.8417
Significance Level of F           0.12444547
Durbin-Watson Statistic             2.005016
Q(35-0)                            38.779189
Significance Level of Q           0.30310411

   Variable                     Coeff       Std Error      T-Stat     Signif
*******************************************************************************
1.  Constant                  3.3029e-005  9.6251e-006      3.43152  0.00079692
2.  RESSQ{1}                       0.2109       0.0860      2.45120  0.01551653
3.  RESSQ{2}                      -0.0861       0.0875     -0.98431  0.32672198
4.  RESSQ{3}                       0.0979       0.0875      1.11890  0.26517111
5.  RESSQ{4}                       0.0166       0.0861      0.19310  0.84716990

Now running GARCH with iib flag on the Australian inflation data

Estimation by BFGS
Iterations Taken    12
Quarterly Data From 1961:04 To 1995:04
Usable Observations    137      Degrees of Freedom   127
Function Value                    627.81061724

   Variable                     Coeff       Std Error      T-Stat     Signif
*******************************************************************************
1.  B0                        2.5214e-003  4.6754e-004      5.39292  0.00000007
2.  B1                             0.4093       0.0223     18.34968  0.00000000
3.  B2                             0.2546       0.0203     12.54842  0.00000000
4.  B3                             0.2411       0.0256      9.41255  0.00000000
5.  B4                             0.0476       0.0132      3.60467  0.00031255
6.  B5                            -0.1209       0.0162     -7.47993  0.00000000
7.  A0                        8.9084e-005  6.7233e-006     13.25002  0.00000000
8.  A1                             0.1253  6.9088e-003     18.13237  0.00000000
9.  A2                            -0.9417       0.0172    -54.62228  0.00000000
10. C0                       -8.7589e-004  8.7355e-004     -1.00267  0.31601845

Correlations of Series RESIDS
Quarterly Data From 1961:03 To 1995:04
Autocorrelations
     1:  0.0241585 -0.1241248 -0.0070245  0.0421229 -0.0127039  0.0768918
     7: -0.1500044  0.0877071 -0.0258186 -0.0071000  0.0389751  0.0788396


Ljung-Box Q-Statistics
Q(8)   =          7.8844.  Significance Level 0.00000000

Below are tests for volatility in residuals
Correlations of Series RESSQ
Quarterly Data From 1960:01 To 1995:04
Autocorrelations
     1:  0.1993611 -0.0186726  0.0911466  0.0612484  0.1458108  0.1001758
```

```
     7: -0.0371403  0.0192520  0.2854787  0.0646106  0.0089178 -0.0483796

Partial Autocorrelations
     1:  0.1993611 -0.0608354  0.1120767  0.0184486  0.1466273  0.0375043
     7: -0.0593313  0.0218801  0.2708184 -0.0665901  0.0242386 -0.1101118


Ljung-Box Q-Statistics
Q(4)   =          7.6970.  Significance Level 0.00000000
Q(8)   =         12.7106.  Significance Level 0.00000000
Q(12)  =         26.4429.  Significance Level 0.00000181


Dependent Variable RESSQ - Estimation by Least Squares
Quarterly Data From 1961:01 To 1995:04
Usable Observations    140      Degrees of Freedom   135
Centered R**2     0.054180      R Bar **2   0.026155
Uncentered R**2   0.248200      T x R**2      34.748
Mean of Dependent Variable      0.0000433248
Std Error of Dependent Variable 0.0000855896
Standard Error of Estimate      0.0000844628
Sum of Squared Residuals        9.63086e-007
Regression F(4,135)                   1.9333
Significance Level of F           0.10844224
Durbin-Watson Statistic             2.005684
Q(35-0)                            41.902265
Significance Level of Q           0.19633039

   Variable                     Coeff       Std Error      T-Stat     Signif
*******************************************************************************
1.  Constant                 3.2391e-005  9.4905e-006      3.41302  0.00084837
2.  RESSQ{1}                      0.2123       0.0861      2.46747  0.01485853
3.  RESSQ{2}                     -0.0847       0.0874     -0.96915  0.33420145
4.  RESSQ{3}                      0.1071       0.0875      1.22429  0.22297340
5.  RESSQ{4}                      0.0188       0.0862      0.21855  0.82733358

***************************************************
****************  Canadian data  ****************
***************************************************
Now running GARCH on the Canadian inflation data

Dependent Variable DLCPI - Estimation by Box-Jenkins
Iterations Taken     3
Quarterly Data From 1961:03 To 1995:04
Usable Observations    138      Degrees of Freedom   132
Centered R**2     0.681820      R Bar **2   0.669768
Uncentered R**2   0.897670      T x R**2     123.878
Mean of Dependent Variable      0.0124889056
Std Error of Dependent Variable 0.0086303807
Standard Error of Estimate      0.0049595170
Sum of Squared Residuals        0.0032467788
Durbin-Watson Statistic             1.996060
Q(34-5)                            36.691587
Significance Level of Q           0.15427833

   Variable                     Coeff       Std Error      T-Stat     Signif
*******************************************************************************
1.  CONSTANT                 0.012595097  0.004017205      3.13529  0.00211657
2.  AR{1}                    0.534687057  0.086997489      6.14601  0.00000001
3.  AR{2}                    0.048775079  0.095271474      0.51196  0.60953524
4.  AR{3}                    0.110555158  0.093255064      1.18551  0.23794417
5.  AR{4}                    0.273435928  0.093648052      2.91983  0.00411966
6.  AR{5}                   -0.072573654  0.085807258     -0.84578  0.39920870


Estimation by BFGS
Iterations Taken    22
Quarterly Data From 1961:04 To 1995:04
Usable Observations    137      Degrees of Freedom   128
Function Value                    665.63276077

   Variable                     Coeff       Std Error      T-Stat     Signif
*******************************************************************************
1.  B0                       3.2031e-004  3.1419e-004      1.01946  0.30798404
2.  B1                            0.6132       0.0650      9.43018  0.00000000
3.  B2                           -0.0177       0.0665     -0.26593  0.79029275
4.  B3                            0.1816       0.0789      2.30039  0.02142638
5.  B4                            0.2438       0.0907      2.68672  0.00721584
6.  B5                           -0.0378       0.0558     -0.67781  0.49789369
7.  A0                       5.3900e-005  5.2866e-006     10.19564  0.00000000
8.  A1                            0.1271       0.0282      4.51434  0.00000635
9.  A2                           -0.9787  6.1587e-003   -158.90767  0.00000000

Correlations of Series RESIDS
Quarterly Data From 1961:03 To 1995:04
Autocorrelations
     1: -0.0648750  0.0411517 -0.0400463 -0.0151520 -0.0153107  0.0191574
     7: -0.0386174  0.1297344 -0.0757484 -0.0818512 -0.0711892  0.0239270


Ljung-Box Q-Statistics
Q(8)   =          3.9058.  Significance Level 0.00000000

Below are tests for volatility in residuals
Correlations of Series RESSQ
Quarterly Data From 1960:01 To 1995:04
Autocorrelations
     1:  0.1798270  0.1832103  0.1528896 -0.0054739 -0.0265839  0.0089987
     7: -0.0463940  0.0095837  0.0205243 -0.1094632  0.0286722  0.0443863

Partial Autocorrelations
     1:  0.1798270  0.1559145  0.1027842 -0.0753839 -0.0603086  0.0194020
     7: -0.0259949  0.0291140  0.0224684 -0.1223318  0.0502232  0.0684372


Ljung-Box Q-Statistics
Q(4)   =         13.2139.  Significance Level 0.00000000
Q(8)   =         13.6776.  Significance Level 0.00000000
Q(12)  =         16.0669.  Significance Level 0.00109872


Dependent Variable RESSQ - Estimation by Least Squares
Quarterly Data From 1961:01 To 1995:04
Usable Observations    140      Degrees of Freedom   135
Centered R**2     0.068614      R Bar **2   0.041017
Uncentered R**2   0.328129      T x R**2      45.938
Mean of Dependent Variable      0.0000238276
Std Error of Dependent Variable 0.0000384768
Standard Error of Estimate      0.0000376794
Sum of Squared Residuals        1.91665e-007
Regression F(4,135)                   2.4863
Significance Level of F           0.04643923
Durbin-Watson Statistic             2.008838
Q(35-0)                            21.382921
Significance Level of Q           0.96579972

   Variable                     Coeff       Std Error      T-Stat     Signif
*******************************************************************************
1.  Constant                 1.6126e-005  4.4754e-006      3.60313  0.00044095
2.  RESSQ{1}                      0.1388       0.0858      1.61777  0.10804724
3.  RESSQ{2}                      0.1487       0.0860      1.72873  0.08614337
4.  RESSQ{3}                      0.1144       0.0862      1.32740  0.18661568
5.  RESSQ{4}                     -0.0785       0.0873     -0.89964  0.36991640

Now running GARCH with iib flag on the Canadian inflation data
```

```
Estimation by BFGS
Iterations Taken    77
Quarterly Data From 1961:04 To 1995:04
Usable Observations    132      Degrees of Freedom   122
 Total Observations    137      Skipped/Missing        5
Function Value                    626.37918372

   Variable                     Coeff       Std Error      T-Stat     Signif
*******************************************************************************
1.  B0                       1.0181e-003  2.1463e-005     47.43365  0.00000000
2.  B1                            0.6612  1.2858e-003    514.21037     NA
3.  B2                           -0.1282       0.0175     -7.30915  0.00000000
4.  B3                            0.0322       0.0165      1.94510  0.05176344
5.  B4                            0.5669  9.5280e-003     59.49382  0.00000000
6.  B5                           -0.2091       0.0186    -11.24245  0.00000000
7.  A0                       5.8653e-005  5.4373e-006     10.78728  0.00000000
8.  A1                            0.1921       0.0128     15.03772  0.00000000
9.  A2                           -0.8680  5.2839e-003   -164.26818  0.00000000
10. C0                      -7.6886e-003  8.2781e-004     -9.28790  0.00000000

Correlations of Series RESIDS
Quarterly Data From 1961:03 To 1995:04
Autocorrelations
     1: -0.0041171  0.1752674  0.2890901 -0.1114622  0.1714795  0.1440929
     7:  0.0376235  0.1621263  0.0449836  0.0130098  0.0164830  0.0547628


Ljung-Box Q-Statistics
Q(8)   =         29.5433.  Significance Level 0.00000000

Below are tests for volatility in residuals
Correlations of Series RESSQ
Quarterly Data From 1960:01 To 1995:04
Autocorrelations
     1:  0.1080521  0.1653438  0.1730209  0.0230296  0.1152540  0.1420067
     7:  0.0285600  0.1382413  0.1481195  0.0540111  0.1045424 -0.0250720

Partial Autocorrelations
     1:  0.1080521  0.1554839  0.1463376 -0.0298106  0.0709896  0.1113591
     7: -0.0146918  0.0811667  0.1076977  0.0042122  0.0215657 -0.0876858


Ljung-Box Q-Statistics
Q(4)   =         10.3075.  Significance Level 0.00000000
Q(8)   =         18.4683.  Significance Level 0.00000000
Q(12)  =         24.1705.  Significance Level 0.00000564


Dependent Variable RESSQ - Estimation by Least Squares
Quarterly Data From 1961:01 To 1995:04
Usable Observations    140      Degrees of Freedom   135
Centered R**2     0.054787      R Bar **2   0.026780
Uncentered R**2   0.343210      T x R**2      48.049
Mean of Dependent Variable      0.0000291331
Std Error of Dependent Variable 0.0000441205
Standard Error of Estimate      0.0000435257
Sum of Squared Residuals        2.55756e-007
Regression F(4,135)                   1.9562
Significance Level of F           0.10475804
Durbin-Watson Statistic             1.981789
Q(35-0)                            19.457934
Significance Level of Q           0.98438890

   Variable                     Coeff       Std Error      T-Stat     Signif
*******************************************************************************
1.  Constant                 1.9934e-005  5.5670e-006      3.58075  0.00047688
2.  RESSQ{1}                      0.0691       0.0871      0.79301  0.42916344
3.  RESSQ{2}                      0.1469       0.0873      1.68266  0.09475156
4.  RESSQ{3}                      0.1473       0.0853      1.72746  0.08637152
5.  RESSQ{4}                     -0.0479       0.1220     -0.39289  0.69501700

***************************************************
****************  British data  ****************
***************************************************
Now running GARCH on the British inflation data

Dependent Variable DLCPI - Estimation by Box-Jenkins
Iterations Taken     3
Quarterly Data From 1961:03 To 1995:04
Usable Observations    138      Degrees of Freedom   132
Centered R**2     0.563569      R Bar **2   0.547037
Uncentered R**2   0.815200      T x R**2     112.498
Mean of Dependent Variable      0.0178374478
Std Error of Dependent Variable 0.0153419147
Standard Error of Estimate      0.0103254946
Sum of Squared Residuals        0.0140732907
Durbin-Watson Statistic             1.943756
Q(34-5)                            45.355887
Significance Level of Q           0.02716340

   Variable                     Coeff       Std Error      T-Stat     Signif
*******************************************************************************
1.  CONSTANT                 0.017614134  0.004619926      3.81264  0.00021011
2.  AR{1}                    0.484778850  0.083204704      5.82634  0.00000004
3.  AR{2}                    0.096958372  0.078142316      1.24079  0.21688329
4.  AR{3}                   -0.065085205  0.078603750     -0.82802  0.40915568
5.  AR{4}                    0.590412741  0.078161524      7.55375  0.00000000
6.  AR{5}                   -0.297373046  0.083372349     -3.56681  0.00050416


Estimation by BFGS
Iterations Taken    40
Quarterly Data From 1961:04 To 1995:04
Usable Observations    137      Degrees of Freedom   128
Function Value                    575.96973904

   Variable                     Coeff       Std Error      T-Stat     Signif
*******************************************************************************
1.  B0                       3.8991e-003  1.3291e-003      2.93369  0.00334953
2.  B1                            0.4465       0.0880      5.07567  0.00000039
3.  B2                            0.0860       0.0678      1.26803  0.20478859
4.  B3                           -0.1540       0.0625     -2.46522  0.01369281
5.  B4                            0.6168       0.0599     10.29565  0.00000000
6.  B5                           -0.3437       0.0747     -4.60311  0.00000416
7.  A0                       1.6267e-005  7.0420e-006      2.30993  0.02089230
8.  A1                            0.6104       0.2728      2.23728  0.02526786
9.  A2                            0.3626       0.1655      2.19114  0.02844181

Correlations of Series RESIDS
Quarterly Data From 1961:03 To 1995:04
Autocorrelations
     1:  0.0895158  0.0553905  0.1180655 -0.0513014  0.0902082  0.1074804
     7:  0.1867694  0.0830697  0.0737779 -0.0285329  0.0682534  0.1029641


Ljung-Box Q-Statistics
Q(8)   =         12.9832.  Significance Level 0.00000000

Below are tests for volatility in residuals
Correlations of Series RESSQ
Quarterly Data From 1960:01 To 1995:04
Autocorrelations
     1:  0.2589474  0.1185329  0.1563065  0.3416185  0.0840944  0.0787642
     7:  0.0873518 -0.0130524 -0.0309647  0.0371847  0.1320549 -0.0293815
```

```
Partial Autocorrelations
     1:  0.2589474  0.0551791  0.1215108  0.2945779 -0.0838234  0.0344055
     7:  0.0050699 -0.1629090 -0.0029129  0.0263705  0.1273215 -0.0286705


Ljung-Box Q-Statistics
Q(4)   =         33.1069.  Significance Level 0.00000000
Q(8)   =         36.3190.  Significance Level 0.00000000
Q(12)  =         39.5793.  Significance Level 0.00000001


Dependent Variable RESSQ - Estimation by Least Squares
Quarterly Data From 1961:01 To 1995:04
Usable Observations    140      Degrees of Freedom   135
Centered R**2     0.162831      R Bar **2   0.138026
Uncentered R**2   0.292334      T x R**2      40.927
Mean of Dependent Variable      0.0001100240
Std Error of Dependent Variable 0.0002581186
Standard Error of Estimate      0.0002396438
Sum of Squared Residuals        0.0000077529
Regression F(4,135)                   6.5645
Significance Level of F           0.00007392
Durbin-Watson Statistic             1.952123
Q(35-0)                            30.993871
Significance Level of Q           0.66197061

   Variable                     Coeff       Std Error      T-Stat     Signif
*******************************************************************************
1.  Constant                 0.0000482503 0.0000244638      1.97231  0.05061778
2.  RESSQ{1}                 0.1994033101 0.0821791146      2.42645  0.01656725
3.  RESSQ{2}                 0.0171282539 0.0838340104      0.20431  0.83841776
4.  RESSQ{3}                 0.0515989659 0.0838380242      0.61546  0.53928702
5.  RESSQ{4}                 0.2961871138 0.0821561664      3.60517  0.00043780

Now running GARCH with iib flag on the British inflation data

Estimation by BFGS
Iterations Taken    26
Quarterly Data From 1961:04 To 1995:04
Usable Observations    137      Degrees of Freedom   127
Function Value                    576.23853493

   Variable                     Coeff       Std Error      T-Stat     Signif
*******************************************************************************
1.  B0                        4.5585e-003  1.4311e-003      3.18533  0.00144588
2.  B1                             0.4412       0.0846      5.21224  0.00000019
3.  B2                             0.0815       0.0555      1.47010  0.14153577
4.  B3                            -0.1569       0.0564     -2.78139  0.00541260
5.  B4                             0.6083       0.0466     13.06586  0.00000000
6.  B5                            -0.3382       0.0701     -4.82706  0.00000139
7.  A0                        1.6638e-005  6.0394e-006      2.75493  0.00587053
8.  A1                             0.6424       0.2762      2.32584  0.02002701
9.  A2                             0.3422       0.1542      2.22003  0.02641682
10. C0                       -8.9944e-004  1.3103e-003     -0.68642  0.49244941

Correlations of Series RESIDS
Quarterly Data From 1961:03 To 1995:04
Autocorrelations
     1:  0.0884641  0.0550252  0.1162260 -0.0472315  0.0867268  0.1024826
     7:  0.1845003  0.0839590  0.0712414 -0.0313921  0.0643109  0.1029079


Ljung-Box Q-Statistics
Q(8)   =         12.4863.  Significance Level 0.00000000

Below are tests for volatility in residuals
Correlations of Series RESSQ
Quarterly Data From 1960:01 To 1995:04
Autocorrelations
     1:  0.2586750  0.1148647  0.1587322  0.3359169  0.0790108  0.0765779
     7:  0.0902764 -0.0155477 -0.0323908  0.0324496  0.1254807 -0.0323362

Partial Autocorrelations
     1:  0.2586750  0.0513906  0.1259941  0.2872212 -0.0860287  0.0359686
     7:  0.0074776 -0.1611103 -0.0016651  0.0199143  0.1207472 -0.0287703


Ljung-Box Q-Statistics
Q(4)   =         32.4933.  Significance Level 0.00000000
Q(8)   =         35.6189.  Significance Level 0.00000000
Q(12)  =         38.6030.  Significance Level 0.00000000


Dependent Variable RESSQ - Estimation by Least Squares
Quarterly Data From 1961:01 To 1995:04
Usable Observations    140      Degrees of Freedom   135
Centered R**2     0.159377      R Bar **2   0.134470
Uncentered R**2   0.288901      T x R**2      40.446
Mean of Dependent Variable      0.0001092957
Std Error of Dependent Variable 0.0002570105
Standard Error of Estimate      0.0002391068
Sum of Squared Residuals        0.0000077182
Regression F(4,135)                   6.3988
Significance Level of F           0.00009570
Durbin-Watson Statistic             1.952026
Q(35-0)                            30.338270
Significance Level of Q           0.69263574

   Variable                     Coeff       Std Error      T-Stat     Signif
*******************************************************************************
1.  Constant                 0.0000483572 0.0000244015      1.98173  0.04954012
2.  RESSQ{1}                 0.1999873428 0.0823742179      2.42779  0.01650865
3.  RESSQ{2}                 0.0137992080 0.0840067780      0.16426  0.86976977
4.  RESSQ{3}                 0.0575716413 0.0840116330      0.68528  0.49434113
5.  RESSQ{4}                 0.2888306011 0.0823510770      3.50731  0.00061519

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*********************  Done  *********************
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