The causal relationship between patent growth and growth of GDP with quarterly data in the G7 countries: cointegration, ARDL and error correction models

Josheski, Dushko and Koteski, Cane
Goce Delcev University-Stip, Goce Delcev University-Stip

03. September 2011

The causal relationship between patent growth and growth of GDP with quarterly data in the G7 countries: cointegration, ARDL and error correction models

Dushko Josheski (e-mail address: dushkojosheski@gmail.com)
Cane Koteski (e-mail address: cane.koteski@ugd.edu.mk)

Abstract

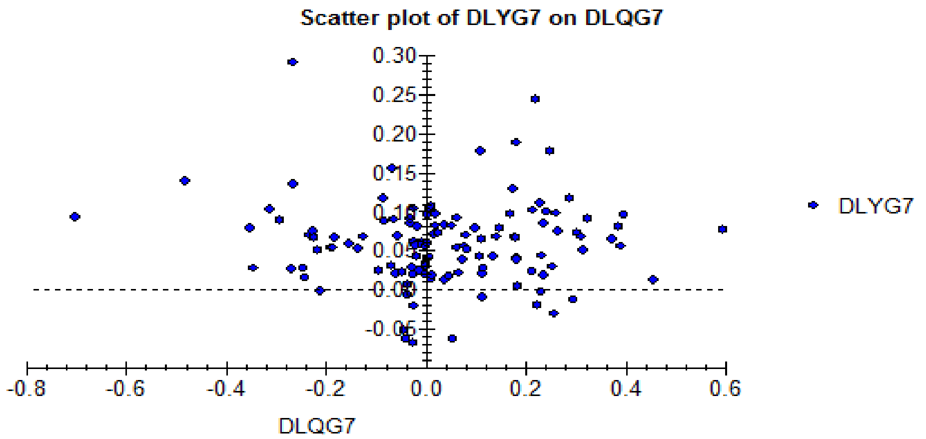
This empirical study investigates the dynamic link between patent growth and GDP growth in G7 economies. ARDL model showed that there exist positive relationship in long run between quarterly growth of patents and quarterly GDP growth. The error correction term suggests that 20,6 percent of the adjustment back to long run equilibrium of industrial production in G7 countries is corrected by 20,6% a year, following a shock like the one in 1974 , which in our study is controlled by a dummy variable D74. In the short run however at one or two lags there exist negative relationship between quarterly patents growth and quarterly growth of GDP. Johansen's procedure for cointegration showed that long run multipliers are positive between the patent growth and GDP growth in G7 economies. Granger causality test showed that patent growth Granger cause GDP growth in G7 countries. Unrestricted VAR showed that there exists positive relationship between patent growth and GDP growth at two or three lags.

Key words: Cointegration, ARDL, Error correction models, Johasens's procedure, Patent growth, GDP growth

Introduction

In 1975 French president Valéry Giscard d'Estaing invited leaders of Germany, Italy, USA, the Unite Kingdom, Japan. The group was discussing oil crisis, stock market crash .So the event was to become annual and that is how the group was formed, later Canada was invited to join and the G7 was created. We use quarterly data on growth of patents and quarterly data of GDP growth (1963Q1 to 1993Q4) from G7 countries, and our purpose here is to estimate the causal relationship between this two variables.

Technological revolution in the twentieth century has happened and more innovations than all the earlier centuries happened. Technology and innovation are seen as engines of economic growth (Usmani, Ahmad, Junoh). Technological change has been regarded as a major source of long-run productivity growth (Romer, 1990, Grossman and Helpman, 1991), with innovation no longer being treated as an exogenous process. Patents have become increasingly important, especially over the past two decades. As patent office procedures have adapted to remain abreast of changing economic and scientific circumstances, it has also become increasingly important to define and analyse innovation more precisely(Mcalleer, Slotje, 2005). In the next graph it is presented the relationship between quarterly growth of patents and quarterly growth of GDP.



Scatter plot of GDP growth quarterly data in G7 countries and growth of quarterly patents in G7 countries data from 1963 Q1 to 1993Q4.

The scatter plot result is ambiguous, meaning that between growth of quarterly patents and quarterly growth of GDP in G7 countries exist positive as well negative relationship. We will test this result empirically in the latter of the paper. The application of the conventional Granger (1969) causality tests is a common practice in empirical research. In the standard Granger-causality test, a variable X_t Granger-causes Y_t if the lagged values of X_t help improve the forecast of Y_t. One of the problems of the conventional Granger-causality tests which Miller and Russek (1990), and Miller (1991) pointed out is that it is possible to find no causal relationship between two variables that share a common trend. This is the case because a variable that exhibits non-stationarity will show no tendency to return to its long-run equilibrium level in the event of a random disturbance; hence the conventional Granger causality tests may lead to misleading results. One of the important features of the cointegration analysis over the standard Granger causality test is that if two variables are integrated of order one, that is $I(1)$, and cointegrated, there must be Granger-causality in at least one direction because one variable can help predict the other(OWOYE,1995).

Data and the methodology

First, in the paper we will use ARDL model to see the long run relationship between this variables. Afterwards we set error correction model to capture short run and long run coefficients as well as the coefficient on the error correction model. Descriptive statistics of the variables and correlation matrix is given as follows:

Descriptive statistics		
	LYG7	LQG7
Maximum	0.37752	51.7423
Mean	-2.4425	47.3223
Minimum	-6.9122	39.8834
Correlation matrix		
	LYG7	LQG7
LYG7	1.00	-
LQG7	.87495	1.00

Autoregressive distributed lag model (ARDL)[1]

In economics we know that rarely Y variable responds instantaneously on X variable let say. Y responds with laps of time. Such a laps of time is called lag (Gujaraty,2003).

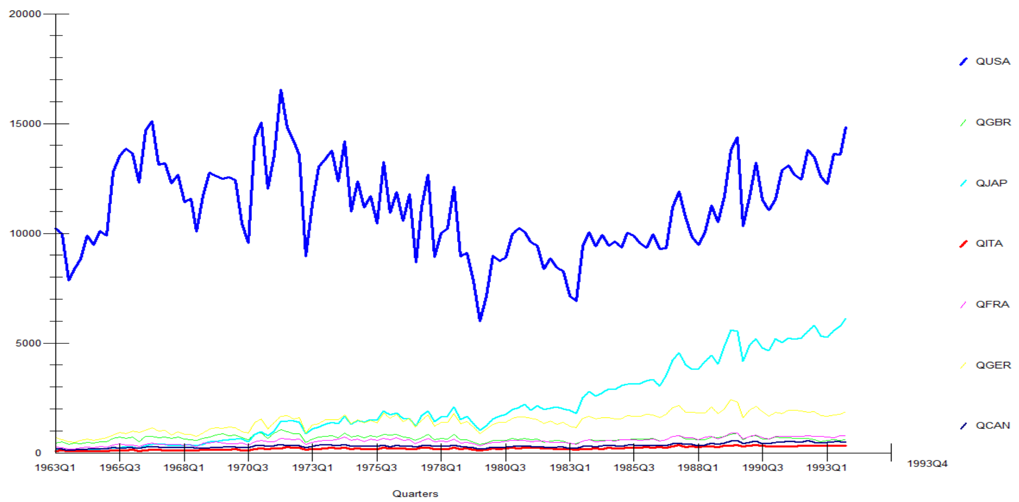
General model with lags is as follows:

$$Y_t = \alpha + \beta_0 X_t + \beta_1 X_{t-1} + ... + \beta_k X_{t-k} + u_t$$

Here β_0 is short run coefficient while, $\sum_{i=0}^{k} \beta_i = \beta_0 + \beta_1 + ... + \beta_k = \beta$, is long run coefficient , or total lag distributed multiplier.

Our ARDL is up to four lags, also here we add dummy variable in the model D74 , this variable is used to control for 1973-1974 stock market crash. This was what followed after great oil crash 1973, and after Bretton Woods fall 1972.

This time series is plotted as follows:



On average highest quarterly patents from 1963 to 1993 has USA, followed by quarterly patents of Japan. The third one in G7 countries is Germany, while other 4, France, Canada, Great Britain, and Italy has similar number of quarterly patents in the period.

Firstly there are lags between growth of quarterly patents and quarterly growth of GDP is because the lag between the invention of an idea or device and its development up to a

[1] See Appendices variables definitions.

commercially applicable stage, and the lag which is introduced by the process of diffusion: it takes time before all the old machines are replaced by the better new ones (Griliches,1967). Also contractual obligations permit patents or innovations from diffusion. Also technological reasons like imperfect knowledge may account for lags. For instance many similar products, or similar patents.

Estimated ARDL model[2] (long run coefficients model) is as follows:

ARDL(3,3,0) selected based on Schwarz Bayesian Criterion		
Dependent variable is DLYG7	Coefficient	p-value
DLYG7(-1)	0.31236	[0.001]
DLYG7(-2)	0.18942	[0.035]
DLYG7(-3)	0.29185	[0.001]
DLQG7	-0.030839	[0.182]
DLQG7(-1)	0.011888	[0.621]
DLQG7(-2)	0.095881	[0.000]
DLQG7(-3)	0.057458	[0.015]
D74	-0.051877	[0.027]
R^2	0.24886	
F-stat	F(7, 110) = 5.2062[.000]	
D-W Statistics	2.0696	

Diagnostics of the model is as follows:

	p-value	**decision**
Serial Correlation[3]	[0.742]	We cannot reject the null hypothesis of no serial correlation at all conventional levels of significance
Functional Form	[0.113]	We cannot reject the null hypothesis for a good functional form at all levels of significance
Normality	[0.000]	We cannot reject the null hypothesis for normality
Heteroscedasticity	[0.422]	We cannot reject the null hypothesis of homoscedasticity at all levels of significance

[2] See Appendix1
[3] This is very important in time series because of the often presence of serial correlation.

D74 is negatively correlated with the quarterly growth of GDP in G7 countries, and the coefficient is statistically and economically significant. Coefficients on the three lags of the growth of quarterly patents in G7 countries are of small size but positively, as expected correlated with the quarterly growth of GDP in G7 countries. Short run coefficient on quarterly patents is negatively associated with the quarterly growth of GDP in G7 countries, but the coefficient itself is insignificant at conventional levels of significance. Also three coefficient on the lags of quarterly growth of GDP in G7 countries are positively and statistically significantly correlated with the quarterly growth of GDP in G7 AR(4) . D-W statistics above 2(>2) suggests negative correlation among the residuals. Serial correlation is not problem in this time series, and functional form is correctly specified according to the diagnostics table of the model. Also heteroscedasticity is not the problem that out model suffers from. So in conclusion long run coefficients are positive, and there exist positive long run relationship between quarterly growth of patents and quarterly growth of GDP in the selected G-7 countries.

Error correction mechanism (ECM) for the selected ARDL model

In the error correction model are captured short run and long run coefficients between the variables of interest. Adjustment towards long run equilibrium is given by the coefficients of the EC mechanism (Harris,Sollis, 2003). Error correction mechanism shows that on average lagged quarterly growth of GDP have negative effects on quarterly growth of GDP itself. Similar lagged quarterly growth of patents in the G7 countries have negative effect on short run at 2 years lag. The coefficients are significant at all conventional levels of significance. The coefficient on the Error correction model is negative and statistically significant p-value (0.003). The error correction term represents the speed of adjustment of the change in the quarterly output to its long run equilibrium following a shock in the short run. Moreover the significance of the error correction term confirms the existence of a long run relationship between the regressors and the dependent variable. The error correction term suggests that 20,6 percent of the adjustment back to long run equilibrium is corrected after one year.

Error correction mechanism is presented in the following table.

(b) **Error Correction Representation for the Selected ARDL Model ARDL selected based on Schwarz Bayesian Criterion**

Dependent variable is dDLYG7		
Variable	Coefficient	t-stat (p-value)
dDLYG7(-1)	-0.48127	-5.1456[0.000]
dDLYG7(-2)	-0.29185	-3.4268[0.001]
dDLQG7	-0.030839	-1.3428[0.182]
dDLQG7(-1)	-0.15334	-4.0106[0.000]
dDLQG7(-2)	-0.057458	-2.4788[0.015]
D74	-0.051877	-2.2459[0.027]
ecm(-1)	-0.20637	-3.0592[0.003]
R^2=0.426	$\bar{R}^2 = 0.39$	
D-W-stat=2.06	Fstat=13.6547[0.000]	

R-Squared and R-Bar-Squared measures refer to the dependent variable dDLYG7 and in cases where the error correction model is highly restricted, these measures could become negative.

Sensitivity analysis		
Test statistic	LM version	F version
I: Serial Correlation	1.9654[0.742]	0.44886[.773]
II: Functional Form	2.5120[0.113]	2.3709[.127]
III :Normality	163.9122[0.000]	n.a.
IV: Heteroscedasticity	0.64474[0.422]	0.63729[0.426]

I: Lagrange multiplier test of residual serial correlation.

II: Ramsey's RESET test using the square of the fitted values.

III: Based on a test of skewness and kurtosis of residuals.

IV: Based on the regression of squared residuals on squared fitted values.

The diagnostic tests also pass the overall validity of the model.This is for all tests except for normality.

Estimated Long Run Coefficients using the ARDL Approach[4]

Next we are estimating the long run coefficient using this 118 observations quarterly data for industrial production (quarterly growth of GDP per capita in G7 countries),

Dependent variable is DLYG7
118 observations used for estimation from 1964Q2 to 1993Q3

DLQG7	0.65120	2.4480[0.016]
D74	-0.25138	-1.8365[0.069]

So in long run increase in 1 percentage points in number of quarterly patents increase quarterly growth of GDP per capita by 0.65% in G7 countries. This coefficient is statistically and economically significant.

Cointegration

Next we do cointegration test with no intercepts or trends. x_t and y_t are said to be cointegrated if there exists a parameter α such that

$$u_t \equiv y_t - \alpha x_t$$

is a stationary process.

The first thing to notice is of course that economic series behave like I(1) processes, i.e. they seem to “drift all over the place"; but the second thing to notice is that they seem to drift in such a way that the they do not drift away from each other. If you formulate this statistically you come up with the cointegration model (Sorensen,2005).

Cointegration with unrestricted intercepts and restricted trends in the VAR

This procedure involves three suggested test tests here for selecting the number of cointegrating vectors. First, we are going to present the results from LR test based on the maximal eingevalue of the stochastic matrix. For order of VAR (4).

[4] See Apendix 2

Cointegration with unrestricted intercepts and restricted trends in the VAR[5]
Cointegration LR Test Based on Maximal Eigenvalue of the Stochastic Matrix

118 observations from 1964Q2 to 1993Q3. Order of VAR = 4.

Null	Alternative	Statistic	95% Critical value	90% critical value
r = 0	r = 1	52.1710	19.2200	17.1800
r <= 1	r = 2	17.9575	12.3900	10.5500

Use the above table to determine r (the number of cointegrating vectors).

Cointegration with unrestricted intercepts and restricted trends in the VAR
Cointegration LR Test Based on Trace of the Stochastic Matrix

118 observations from 1964Q2 to 1993Q3. Order of VAR = 4.

Null	Alternative	Statistic	95% Critical value	90% critical value
r = 0	r >= 1	70.1284	25.700	23.0800
r <= 1	r = 2	17.9575	12.3900	10.5500

Use the above table to determine r (the number of cointegrating vectors).

Cointegration with unrestricted intercepts and restricted trends in the VAR
Choice of the Number of Cointegrating Relations Using Model Selection Criteria

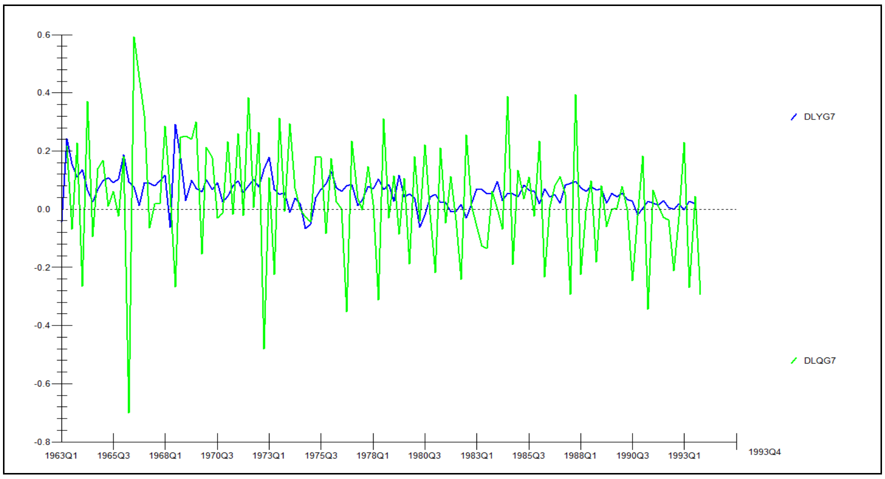
118 observations from 1964Q2 to 1993Q3. Order of VAR = 4.

rank	Maximized LL	AIC	SBC	HQC
r = 0	215.6245	201.6245	182.2297	193.7497
r = 1	241.7100	223.7100	198.7738	213.5852
r= 2	250.6887	230.6887	202.4389	219.4389

AIC = Akaike Information Criterion SBC = Schwarz Bayesian Criterion
HQC = Hannan-Quinn Criterion

[5] See Appendix 3

So from this three tables we choose two cointegrating vectors , maximum possible. From the third table option r=2 has highest AIC info criteria , also from previous two tables we reject the null hypothesis of r=0 in favor of r>=1 , but also r<=1 is rejected in favor of r=2 , so we acept r=2. Next figure shows that second difference of the two variables quarterly growth of GDP per capita in G7 countries (DLYG7) , and growth of quarterly patents in G7 countries (DLQG7) are I(2) variables.



Johansen's just identifying restrictions

We use Johansen's just identifying restrictions to display CV's i.e. cointegrating vectors.

Estimated Cointegrated Vectors in Johansen Estimation (Normalized in Brackets)
Cointegration with unrestricted intercepts and restricted trends in the VAR

118 observations from 1964Q2 to 1993Q3. Order of VAR = 4, chosen r =2.

	Vector 1	Vector 2
DLYG7	0.80508	3.1108
	(-1.0000)	(-1.0000)
DLQG7	-1.4272	0.64493
	(1.7728)	(-.20732)
Trend	-0.0013190	.0025745
	(0.0016383)	(-0.8276E-3)

Vector 2 of DLQG7 variable quarterly growth of patents is positive, as it is shown in the Table. While first vector is negative.

Matrix for long run multipliers for the specified 2 vectors in Johansen's estimation[6]

In this section also of importance is to present the matrix of long run multipliers , because we are interested in long run relationship between the two variables of interest.

Estimated Long Run Matrix in Johansen Estimation
Cointegration with no intercepts or trends in the VAR

118 observations from 1964Q2 to 1993Q3. Order of VAR = 4, chosen r =1
List of variables included in the cointegrating vector:
DLYG7 DLQG7

	DLYG7	DLQG7
DLYG7	-0.17149	0.21227
DLQG7	1.1763	-1.4560

Here estimated long run multipliers between DLYG7 (quarterly growth of output in G7 countries), and DLQG7(quarterly growth of patents in G7 countries) is positive.

OLS estimation of unrestricted VAR

Vector auto regression model is basically an econometric model used to capture the interdependence between multiple time series. In the independent variables there is lagged values of the right hand side variable, and other two variables in our case DLQG7 (quarterly growth of patents in G7 countries) and D74,dummy variable used to control for 1974 crisis. In the next Table are given the results from the unrestricted VAR estimation. You can see the software imprint in Appendix 4.

[6] See Appendix 4

OLS estimation of a single equation in the Unrestricted VAR		
Dependent variable is DLYG7	Coefficient	p-value
DLYG7(-1)	0.25	[0.012]
DLYG7(-2)	0.17	[0.076]
DLYG7(-3)	0.32	[0.001]
DLYG7(-4)	-0.003	[0.968]
DLQG7 (-1)	0.016	[0.503]
DLQG7(-2)	0.092	[0.000]
DLQG7(-3)	0.0801	[0.002]
DLQG7(-4)	0.0312	[0.197]
D74(-1)	-0.04	[0.264]
D74(-2)	-0035	[0.449]
D74(-3)	-0.18	[0.695]
D74(-4)	0.078	[0.028]
R^2	0.29	
F-stat	F(11, 106) = 3.8751[.000]	
D-W Statistics	2.0832	

This unrestricted VAR estimation shows that on 2 and 3 lags DLQG7 coefficient is positive and statistically significantly correlated with with growth of quarterly output in G7 countries DLYG7. And the lagged values of DLYG7 are positively and statistically significantly correlated with itself but at 2 and 3 lags. While lagged dummy variable is insignificant except at 4 lags and is negatively correlated with DLYG7.

Sensitivity analysis		
Test statistic	LM version	F version
I: Serial Correlation	5.5894[0.232]	1.2679[.288]
II: Functional Form	5.1279[0.024]	4.7702[.031]
III :Normality	218.9722[.000]	n.a.
IV: Heteroscedasticity	0.42751[.513]	0.42179[.517]

I: Lagrange multiplier test of residual serial correlation.

II: Ramsey's RESET test using the square of the fitted values.

III: Based on a test of skewness and kurtosis of residuals.

IV: Based on the regression of squared residuals on squared fitted values.

The diagnostic tests also pass the overall validity of the model.This is for all tests except for normality.

Test Statistics and Choice Criteria for Selecting the Order of the VAR Model

In the following Table are presented the info criteria for selecting the number of lags.

Order	LL	AIC	SBC	LR test	Adjusted LR test
4	340.7379	304.7379	254.8656	------	------
3	329.0688	302.0688	264.6646	CHSQ(9)= 23.3382[.005]	20.9648[.013]
2	313.0761	295.0761	270.1400	CHSQ(18)= 55.3236[.000]	49.6975[.000]
1	294.5061	285.5061	273.0380	CHSQ(27)= 92.4637[.000]	83.0606[.000]
0	193.2824	193.2824	193.2824	CHSQ(36)= 294.9112[.000]	264.9202[.000]

We selected the 4 number of lags as because the AIC has highest info value. That is the section that is highlighted yellow in the table above.

Test of Serial Correlation of Residuals (OLS case)

Serial correlation is one of the biggest problems in time series data so here we are testing even though formal LM test suggested that serial correlation is not a problem in our models.

Test of Serial Correlation of Residuals (OLS case)

Dependent variable is DLYG7

List of variables in OLS regression:

DLYG7(-1) DLYG7(-2) DLYG7(-3) DLYG7(-4) DLQG7(-1)
DLQG7(-2) DLQG7(-3) DLQG7(-4) D74(-1) D74(-2)
D74(-3) D74(-4)

118 observations used for estimation from 1964Q2 to 1993Q3

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
OLS RES(- 1)	-1.0106	0.46707	-2.1637[0.033]
OLS RES(- 2)	0.15318	0.32501	0.47132[0.638]
OLS RES(- 3)	0.010309	0.28017	0.036795[0.971]
OLS RES(- 4)	-0.12091	0.19083	-0.63363[0.528]

Lagrange Multiplier Statistic CHSQ(4)= 5.5894[0.232]

F Statistic F(4, 102)= 1.2679[0.288]

LM test again showed that we have insufficient evidence to reject H_0 of no serial correlation since the p-value of the test is (0.232) , also F statistic has high p-value (0.288).

Granger causality test

Granger causality test is performed to see whether X lagged variable cause Y variable. In this case to see whether DLQG7 cause DLYG7. The test is given in the Table below.

```
LR Test of Block Granger Non-Causality in the VAR

Based on 118 observations from 1964Q2 to 1993Q3. Order of VAR = 4
List of variables included in the unrestricted VAR:
DLYG7           DLQG7
Maximized value of log-likelihood =  238.6742

List of variable(s) assumed to be "non-causal" under the null hypothesis:
DLQG7
Maximized value of log-likelihood =  231.0158

LR test of block non-causality, CHSQ(  4)=  15.3169[.004]

The above statistic is for testing the null hypothesis that the coefficients
of the lagged values of:
DLQG7
in the block of equations explaining the variable(s):
DLYG7
are zero. The maximum order of the lag(s) is 4.
```

LR test shows that we have enough evidence to reject the null hypothesis of insignificant lagged values of DLQG7 in the block equations explaining the variable DLYG7.

Critical values of chi-square statistics from the Tables

	Probability of exceeding the critical value				
df	0.10	0.05	0.025	0.01	0.001
4	7.779	9.488	11.143	13.277	18.467

Our estimated chi-square statistics 15.319 is > (7.779, 9.488, 11.143, 13.277) at 4 degrees of freedom (df). So we can reject the null and accept the alternative hypothesis that DLQG7 granger causes DLYG7.

So in long run, as conclusion we can confirm that there exists positive relationship between growth of quarterly patents DLQG7 and quarterly growth of GDP in G7 countries DLYG7 variable. While the error correction mechanism showed negative signs on the DLQG7 variable.

Appendices

DLYG7-GROWTH OF QUARTERLY OUTPUT IN G7 COUNTRIES FOR THE PERIOD 1963Q1 TO 1993Q4

DLQG7-GROWTH OF QUARTERLY PATENTS IN G7 COUNTRIES FOR THE PERIOD 1963Q1 TO 1993Q4

D74-DUMMY VARIABLE(0,1) TO CONTROL FOR THE STOCK MARKET CRISIS IN 1974 THAT FOLLOWED GREAT OIL CRASH AND FALL OF BRETTON-WOODS SYSTEM.

TIME-TIME TREND VARIABLE

G7 COUNTRIES ARE- United States of America, France, Germany, Italy, Japan, United Kingdom and Canada.

Appendix 1

```
Autoregressive Distributed Lag Estimates
          ARDL(3,3,0) selected based on Schwarz Bayesian Criterion
*******************************************************************************
 Dependent variable is DLYG7
 118 observations used for estimation from 1964Q2 to 1993Q3
*******************************************************************************
 Regressor              Coefficient       Standard Error         T-Ratio[Prob]
 DLYG7(-1)                   .31236            .087264             3.5795[.001]
 DLYG7(-2)                   .18942            .088749             2.1343[.035]
 DLYG7(-3)                   .29185            .085166             3.4268[.001]
 DLQG7                    -.030839             .022966            -1.3428[.182]
 DLQG7(-1)                  .011888            .023946             .49646[.621]
 DLQG7(-2)                  .095881            .023754             4.0365[.000]
 DLQG7(-3)                  .057458            .023180             2.4788[.015]
 D74                      -.051877             .023098            -2.2459[.027]
*******************************************************************************
 R-Squared                       .24886   R-Bar-Squared                   .20106
 S.E. of Regression             .044562   F-stat.    F(  7, 110)    5.2062[.000]
 Mean of Dependent Variable     .056314   S.D. of Dependent Variable     .049855
 Residual Sum of Squares         .21843   Equation Log-likelihood       203.7908
 Akaike Info. Criterion        195.7908   Schwarz Bayesian Criterion    184.7080
 DW-statistic                    2.0696
*******************************************************************************


                               Diagnostic Tests
*******************************************************************************
*    Test Statistics  *        LM Version        *         F Version          *
*******************************************************************************
*                     *                          *                            *
* A:Serial Correlation*CHSQ(   4)=   1.9654[.742]*F(   4, 106)=   .44886[.773]*
*                     *                          *                            *
* B:Functional Form   *CHSQ(   1)=   2.5120[.113]*F(   1, 109)=   2.3709[.127]*
*                     *                          *                            *
* C:Normality         *CHSQ(   2)= 163.9122[.000]*       Not applicable       *
*                     *                          *                            *
* D:Heteroscedasticity*CHSQ(   1)=   .64474[.422]*F(   1, 116)=   .63729[.426]*
*******************************************************************************
   A:Lagrange multiplier test of residual serial correlation
   B:Ramsey's RESET test using the square of the fitted values
   C:Based on a test of skewness and kurtosis of residuals
   D:Based on the regression of squared residuals on squared fitted values
```

Appendix 2

```
Error Correction Representation for the Selected ARDL Model
          ARDL(3,3,0) selected based on Schwarz Bayesian Criterion
*******************************************************************************
 Dependent variable is dDLYG7
 118 observations used for estimation from 1964Q2 to 1993Q3
*******************************************************************************
 Regressor              Coefficient       Standard Error         T-Ratio[Prob]
 dDLYG71                   -.48127             .093529          -5.1456[.000]
 dDLYG72                   -.29185             .085166          -3.4268[.001]
 dDLQG7                  -.030839              .022966          -1.3428[.182]
 dDLQG71                   -.15334             .038234          -4.0106[.000]
 dDLQG72                 -.057458              .023180          -2.4788[.015]
 dD74                    -.051877              .023098          -2.2459[.027]
 ecm(-1)                   -.20637             .067460          -3.0592[.003]
*******************************************************************************
 List of additional temporary variables created:
 dDLYG7 = DLYG7-DLYG7(-1)
 dDLYG71 = DLYG7(-1)-DLYG7(-2)
 dDLYG72 = DLYG7(-2)-DLYG7(-3)
 dDLQG7 = DLQG7-DLQG7(-1)
 dDLQG71 = DLQG7(-1)-DLQG7(-2)
 dDLQG72 = DLQG7(-2)-DLQG7(-3)
 dD74 = D74-D74(-1)
 ecm = DLYG7   -.65120*DLQG7 +   .25138*D74
*******************************************************************************
 R-Squared                       .42687   R-Bar-Squared                   .39040
 S.E. of Regression             .044562   F-stat.    F(  6, 111)   13.6547[.000]
 Mean of Dependent Variable -.9946E-3   S.D. of Dependent Variable     .057074
 Residual Sum of Squares         .21843   Equation Log-likelihood       203.7908
 Akaike Info. Criterion        195.7908   Schwarz Bayesian Criterion    184.7080
 DW-statistic                    2.0696
*******************************************************************************
 R-Squared and R-Bar-Squared measures refer to the dependent variable
 dDLYG7 and in cases where the error correction model is highly
 restricted, these measures could become negative.
```

```
Estimated Long Run Coefficients using the ARDL Approach
          ARDL(3,3,0) selected based on Schwarz Bayesian Criterion
*******************************************************************************
 Dependent variable is DLYG7
 118 observations used for estimation from 1964Q2 to 1993Q3
*******************************************************************************
 Regressor              Coefficient       Standard Error         T-Ratio[Prob]
 DLQG7                      .65120              .26601           2.4480[.016]
 D74                       -.25138              .13688          -1.8365[.069]
*******************************************************************************
```

Appendix 3

```
Cointegration with unrestricted intercepts and restricted trends in the VAR
   Cointegration LR Test Based on Maximal Eigenvalue of the Stochastic Matrix
*******************************************************************************
 118 observations from 1964Q2 to 1993Q3. Order of VAR = 4.
 List of variables included in the cointegrating vector:
 DLYG7           DLQG7           Trend
 List of eigenvalues in descending order:
.35733     .14117      .0000
*******************************************************************************
 Null    Alternative    Statistic     95% Critical Value     90% Critical Value
 r = 0      r = 1        52.1710           19.2200                 17.1800
 r<= 1      r = 2        17.9575           12.3900                 10.5500
*******************************************************************************
 Use the above table to determine r (the number of cointegrating vectors).
```

```
Cointegration with unrestricted intercepts and restricted trends in the VAR
          Cointegration LR Test Based on Trace of the Stochastic Matrix
*******************************************************************************
 118 observations from 1964Q2 to 1993Q3. Order of VAR = 4.
 List of variables included in the cointegrating vector:
 DLYG7           DLQG7           Trend
 List of eigenvalues in descending order:
.35733     .14117      .0000
*******************************************************************************
 Null    Alternative    Statistic     95% Critical Value     90% Critical Value
 r = 0      r>= 1        70.1284           25.7700                 23.0800
 r<= 1      r = 2        17.9575           12.3900                 10.5500
*******************************************************************************
 Use the above table to determine r (the number of cointegrating vectors).
```

```
Cointegration with unrestricted intercepts and restricted trends in the VAR
Choice of the Number of Cointegrating Relations Using Model Selection Criteria
*******************************************************************************
 118 observations from 1964Q2 to 1993Q3. Order of VAR = 4.
 List of variables included in the cointegrating vector:
 DLYG7           DLQG7           Trend
 List of eigenvalues in descending order:
.35733     .14117      .0000
*******************************************************************************
 Rank      Maximized LL        AIC            SBC            HQC
 r = 0       215.6245       201.6245       182.2297       193.7497
 r = 1       241.7100       223.7100       198.7738       213.5852
 r = 2       250.6887       230.6887       202.9819       219.4389
*******************************************************************************
 AIC = Akaike Information Criterion    SBC = Schwarz Bayesian Criterion
 HQC = Hannan-Quinn Criterion
```

Appendix 4

```
Estimated Long Run Matrix in Johansen Estimation
             Cointegration with no intercepts or trends in the VAR
*******************************************************************************
 118 observations from 1964Q2 to 1993Q3. Order of VAR = 4, chosen r =1.
 List of variables included in the cointegrating vector:
 DLYG7           DLQG7
*******************************************************************************
                    DLYG7          DLQG7
 DLYG7               -.17149         .21227

 DLQG7                1.1763        -1.4560

*******************************************************************************
```

```
OLS estimation of a single equation in the Unrestricted VAR
*******************************************************************************
 Dependent variable is DLYG7
 118 observations used for estimation from 1964Q2 to 1993Q3
*******************************************************************************
 Regressor              Coefficient       Standard Error         T-Ratio[Prob]
 DLYG7(-1)                  .24577            .095593            2.5710[.012]
 DLYG7(-2)                  .16631            .092673            1.7946[.076]
 DLYG7(-3)                  .32386            .091076            3.5560[.001]
 DLYG7(-4)               -.0035231            .087898          -.040081[.968]
 DLQG7(-1)                 .015439            .022997            .67133[.503]
 DLQG7(-2)                 .092354            .024091            3.8336[.000]
 DLQG7(-3)                 .080142            .025360            3.1602[.002]
 DLQG7(-4)                 .031199            .024036            1.2980[.197]
 D74(-1)                  -.039840            .035465           -1.1233[.264]
 D74(-2)                  -.034749            .045725           -.75995[.449]
 D74(-3)                  -.017797            .045265           -.39318[.695]
 D74(-4)                   .078542            .035262            2.2274[.028]
*******************************************************************************
 R-Squared                     .28680   R-Bar-Squared                    .21279
 S.E. of Regression           .044233   F-stat.    F( 11, 106)    3.8751[.000]
 Mean of Dependent Variable   .056314   S.D. of Dependent Variable      .049855
 Residual Sum of Squares       .20740   Equation Log-likelihood        206.8491
 Akaike Info. Criterion      194.8491   Schwarz Bayesian Criterion     178.2250
 DW-statistic                  2.0832   System Log-likelihood          340.7379
*******************************************************************************
```

```
                               Diagnostic Tests
*******************************************************************************
*    Test Statistics  *        LM Version        *         F Version          *
*******************************************************************************
*                     *                          *                            *
* A:Serial Correlation*CHSQ(   4)=   5.5894[.232]*F(   4, 102)=   1.2679[.288]*
*                     *                          *                            *
* B:Functional Form   *CHSQ(   1)=   5.1279[.024]*F(   1, 105)=   4.7702[.031]*
*                     *                          *                            *
* C:Normality         *CHSQ(   2)= 218.9722[.000]*       Not applicable       *
*                     *                          *                            *
* D:Heteroscedasticity*CHSQ(   1)=   .42751[.513]*F(   1, 116)=   .42179[.517]*
*******************************************************************************
   A:Lagrange multiplier test of residual serial correlation
   B:Ramsey's RESET test using the square of the fitted values
   C:Based on a test of skewness and kurtosis of residuals
   D:Based on the regression of squared residuals on squared fitted values
```

References

1. Artis, M.J., Kontolemis,Z.,G., Osborn, R.,D.,(1997), *Business Cycles for G7 and European Countries*, The Journal of Business, Vol. 70, No. 2 (April 1997), pp. 249-279
2. Barro, Robert J., and Xavier Sala-i-Martin, ***Economic Growth***, 2nd edition, Cambridge, MA: MIT Press, 2004.
3. Engle, Robert F., Granger, Clive W. J. (1987) "***Co-integration and error correction: Representation, estimation and testing***", *Econometrica*, 55(2), 251-276.
4. Griliches, Zvi, 1981. "***Market value, R&D, and patents***," Economics Letters, Elsevier, vol. 7(2), pages 183-187.
5. Gujarati, Damodar N.(2004), ***Basic Econometrics***. New York: McGraw-Hill,
6. Harris, R., Sollis,R**., (2003),** ***Applied Time Series Modelling and Forecasting***,
7. John Bound & Clint Cummins & Zvi Griliches & Bronwyn H. Hall & Adam B. Jaffe, 1984. "***Who Does R&D and Who Patents***?," NBER Chapters, in: R & D, Patents, and Productivity, pages 21-54 National Bureau of Economic Research, Inc.
8. Lerner, Josh, "***The Empirical Impact of Intellectual Property Rights on Innovation: Puzzles and Clues***", American Economic Review: Papers and Proceedings of the American Economic Association, Vol. 99 No. 2, May 2009, 343–8.
9. Lerner, Joshua, "***Patent policy shifts and innovation over 150 years***", American Economic Review: Papers and Proceedings of the American Economic Association, Vol. 92 No. 2, May 2002, 221–5.
10. Owoye, O., (1995), ***The causal relationship between taxes and expenditures in the G7 countries: cointegration and error-correction models,*** Applied Economics Letters, 1995, **2**, 19–22
11. Qazi, M., Hue, A.,(2009), ***Agriculture on the Road to Industrialisation and Sustainable Economic growth: An Empirical Investigation for Pakistan***, International Journal of Agricultural Economics & Rural Development - 2 (2): 2009
12. Qian, Yi, (2007), "***Do Additional National Patent Laws Stimulate Domestic Innovation in a Global Patenting Environment: A Cross-Country Analysis of Pharmaceutical Patent Protection***, 1978–2002", Review of Economics and Statistics, Vol. 89, No. 3, August 2007, 436-453
13. Vichyanond, Jade, "***Intellectual Property Protection and Patterns of Trade", Department of Economics***, Princeton University, November 2009.
14. Zvi Griliches, 1984. "***Introduction to "R & D, Patents, and Productivity***"," NBER Chapters, in: R & D, Patents, and Productivity
15. Zvi Griliches, 1984. "***R & D, Patents, and Productivity***," NBER Books, National Bureau of Economic Research, Inc, number gril84-1, March.