ANWESHAN, Vol. 5, No. 1, March 2017

Growth-Inflation nexus in USA: A Threshold Regression Approach

Dr. Debesh Bhowmik[1]
(Retired Principal and Associated in International Institute for Development Studies,
Kolkatadebeshbhowmik@rediffmail.com)
Dr. Debasish Biswas[2]
Assistant Professor, Department of Business Administration,
Vidyasagar University, West Bengal.
debasish762010@yahoo.com)
Prof. Debabrata Mitra[3]
Professor, Department of Commerce,
University of North Bengal, West Bengal.
Email: debabrata_nbu@yahoo.co.in

Abstract

The paper endeavors to find out the nature of inflation of USA during 1961-2015 and to find out the nexus between inflation and growth using Granger causality, Johansen co-integration and vector error correction models. It also showed threshold limit of inflation of 1.75-3.0 per cent in USA using GDP deflator as inflation and taking World Bank Data. It finds one structural break at 1992 and no random walk with drift. Growth inflation nexus is negative. They are co-integrated and showed unidirectional causality. Error correction process is very fast and significant but vector error correction model is stable but divergent. Federal Reserve Bank is in favour of fiscal and monetary policy reforms to curb inflation.

Keywords: Inflation, Economic growth, Granger Causality, Vector Error Correction, Threshold, Monetary policy.

JEL:C13,E22,E31,E37,E52,O40,O49

Introduction

The relationship between inflation and economic growth plays an important role in the economy. High and stable output growth and low inflation are the two main goals of macroeconomic policy. In the economic literature, there has been considerable debate on the nature of inflation and growth relationship. Mundel (1965) and Tobin (1965) predict a positive relationship between the rate of inflation and the rate of capital accumulation, which in turn, implies a positive relationship to the rate of economic growth. Fischer and Modigliani (1978) suggest a negative and nonlinear relationship between the rate of inflation and economic growth through the new growth theory mechanism. They mention that inflation restricts economic growth largely by reducing the efficiency of investment rather than its level. Both the views of the structuralists and the monetarists up to a certain extent, that is, low inflation is helpful for economic growth but once the economy achieves faster growth then inflation is detrimental for

the sustainability of such growth. High inflation can cause companies or investors to shift resources away from high to low inflation countries as a hedge against losses that might be generated from rising costs of inflation. However, low inflation levels promote economic growth by making prices and wages more flexible. If high inflation is detrimental for the economy and low inflation is beneficial, then it is natural to ask what the optimal level of inflation for an economy is. For each country or group of countries there exists a certain level or a range of inflation (threshold inflation) which is conducive for growth. If inflation is indeed harmful for economic growth when it reaches a particular threshold level, then knowing this level as well as potential losses of output growth in the short run and in the long run is crucial for formulating macroeconomic policies. Hence it is important to investigate the existence and nature of the link between these two variables.

Objectives

This paper tries to show the behavior of inflation (measured by GDP deflator) of USA during 1961-2015 and to find out nexus between growth and inflation with the help of Granger Causality test,Johansen cointegration rank test and vector error correction model.The paper also tried to calculate the threshold rate of inflation which can be treated as target rate of inflation in USA.

Data and Methodology

Semilog linear regression model was used for trendline. Bai-Perron(2003) model was used for finding structural breaks and random walk with drift model was taken for showing randomness. Double-log non-linear model was used to find relation between growth and inflation of USA during 1961-2015.Granger(1969) model was used to show causality between growth and inflation in USA. Johansen Cointegration and VEC model (1988,1991,1996,)were used to study cointegration test and error correction process towards equilibrium whose residual tests were also done. Threshold inflation model was accepted for finding target rate of inflation for USA following Khan and Senhadji (2001).The data of GDP growth rate and GDP deflator of USA during 1961-2015 were collected from the World Bank.

Literature Studied

Ahmed and Mortaza (2005) explored the relationship between real GDP and CPI using a non-linear approach and established a threshold at 6 percent level of inflation for the economy of Bangladesh. The empirical evidence demonstrates that there exists a statistically significant long-run negative relationship between these two variables.

Pollin and Zhu (2005) presented panel regression estimates from a non-linear model form of quadratic functionof the relationship between inflation and economic growth for 80 countries

over the period 1961–2000. They found threshold inflation ranges of 14-16% for middle-income countries and 15-23% for low-income countries.

Munir et al. (2009) analyzed the non-linear relationship between inflation level and economic growth rate for the period 1970-2005 in the economy of Malaysia. Using annual data and applying new endogenous threshold autoregressive (TAR) models proposed by Hansen (2000), they found an inflation threshold value existing for Malaysia and verify the view that the relationship between inflation rate and economic growth is nonlinear. The estimated threshold regression model suggested 3.89 percent as the structural break point of inflation above which inflation significantly hurts growth rate of real GDP. In addition, below the threshold level, there is statistical significant positive relationship between inflation rate and growth.

Frimpong and Oteng-Abayie (2010) analyzed the threshold effect of inflation on economic growth in Ghana for the period of 1960-2008 by using threshold regression models. The result indicated inflation threshold level of 11% at which inflation starts to significantly hurt economic growth in Ghana. Below the 11% level, inflation was likely to have a mild effect on economic activities, while above this threshold level, inflation would adversely affect economic growth.

Espinoza et al. (2010) examined threshold effect of inflation on GDP growth using a panel data of 165 countries including oil exporting countries. A smooth transition model used over the period of 1960–2007 indicates that for all country groups threshold level of inflation for GDP growth is about 10 percent (except for advanced countries where threshold is much lower). They also separated non-oil exporting countries and found that inflation from higher than 13 percent decreases real non-oil GDP by 2.7 percent per year. Also Rutayisire (2013) estimated a threshold level of inflation in Rwanda using a quadratic regression model with time series data from 1968 to 2010. His findings indicate that the economy of Rwanda can be supported by the rate of inflation which does not exceed 14.97 percent. Kremer, Bick and Nautz (2013) investigated the presence of threshold effects of inflation on long term economic growth using data of a panel for 124 industrial and developing countries. Their empirical results showed that the estimated inflation threshold level was about 2.5% for industrial countries and 17 percent for developing countries; above these critical levels, inflation rate leads to lower long-term economic growth rate in both cases. In addition, the study indicated that below these thresholds, the effect of inflation on long-term economic growth was significantly positive in developed countries; in contrast, there was no significant impact on economic growth in developing countries when inflation is below 17 percent. Nell (2000) examined the issue whether inflation is always harmful to growth or not. The author applied the South African economy's data for the period 1960-1999 and divided it into four periods. Using Vector Auto Regressive (VAR) technique, the empirical results suggested that inflation within the single-digit zone may be beneficial to growth, while inflation in the double digit zone appeared to impose costs in terms of slower growth. Khan and Senhadji (2001) examined threshold effects of inflation on growth separately for industrial and developing countries. The data set covered 140 countries from both groups and non-linear least squares (NLLS) and conditional least squares methods were used. The empirical results verified the existence of a threshold beyond which inflation exerts a negative effect on growth. The study

established statistically significant thresholds at 1-3 percent and 11-12 percent inflation levels for industrialized and developing countries, respectively. The view of low inflation for sustainable growth was strongly supported by this study. Shahnawaz Malik (2011) explores the nexus between inflation and economic growth in the context of Pakistan economy during 1960-2006 where inflation is positively related with economic growth in Pakistan and vice versa. The causality between these two variables is uni-directional. The Error Correction Model (ECM) test is essential to see whether an economy is converging towards equilibrium in the short- run or not. According to the outcome of the study, inflation is away from its equilibrium value. For instance, the error correction term -0.49 implies that 49 percent of the adjustments towards the short-run equilibrium relation for Pakistan occur within a year through changes in growth rates. On the other hand, 58 percent (error correction term -0.58) of the deviation of the inflation from its short-run equilibrium level is corrected each year. Furthermore, the estimated threshold model suggest that 9 percent threshold level (i.e. structural break point) of inflation above which inflation starts to lower the economic growth in Pakistan. Using the VAR ,Granger causality block exogeneity, Wald Tests, Mba Fokwa Arsène & Dazoue Dongue Guy-Paulin(2013) for Cameroon during 1965-2010 showed the inflation has a positive and significant effect on growth, economic growth has a positive and significant effect on credit to the economy and credit to the economy has a negative and significant effect on inflation. Inflation granger causes economic growth, economic growth granger causes credit to the private sector and credit to the private sector granger causes inflation. Sergii Pypko (2009) investigated the growth-inflation interaction for CIS countries for the period of 2001-2008 and found that this relation is strictly concave with some threshold level of inflation at 8%.P.Nandeeswara Rao &Abate Yesigat(2015) focus nature of inflation-economic growth relationship ofEthiopia from 1974 to 2012, specifically by using the frameworkof Vector Auto Regressive (VAR), Error Correction Mechanism(ECM), causality test and threshold level analysis and found that theexistence of long run relationship among the variables entered inthe models. The Granger Causality Test found the bidirectionalcausal relationship between inflation and economic growth. Andthe result also reveals the negative relationship between inflationand economic growth in Ethiopia both in the short and long run.The threshold model estimation recommends 9-10 percent. Saaed, Afaf A.J.(2007) showed relation between real GDP and CPI for the period of 1985 to 2005 in Kuwait and found that there exists a statistically significant long-run negative relationship between inflation and economic growth for the country as indicated by a statistically significant long-run negative relationship between CPI and real GDP.

Overview of the Econometric Models.

Inflation rate (measured by GDP deflator) of USA during 1961-2015 has been declining at the rate of 1.58% per year which is statistically significant at 5% level.The estimated equation is given below.

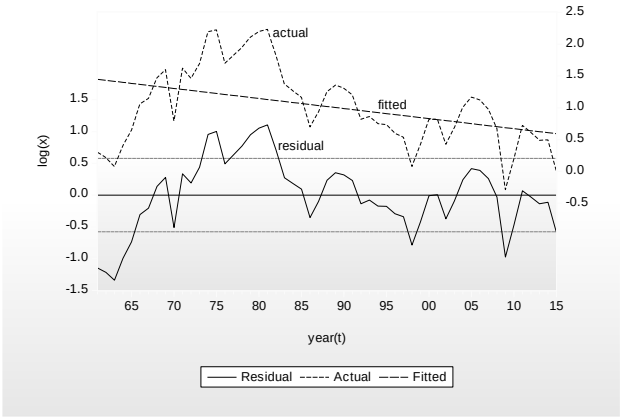
Log(x)=1.461711-0.015818t

(9.26)* (-3.22)*

R^2=0.164,F=10.419* ,DW=0.348 , *= significant at 5% level,x= inflation rate per cent per annum measured by GDP deflator.,t=year

In Fig-1,the fitted trend line,the actual line and the residuals are seen clearly.

Fig-1: Estimated linear trend line of inflation rate



Source-Computed by author

The inflation rate of USA during 1961-2015 does not follow random walk with drift hypothesis which was estimated as shown below.

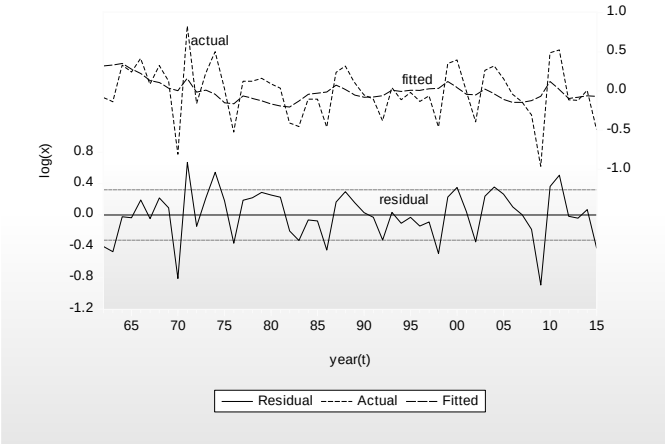
$dlog(x_t)=0.392793-0.202691log(x_{t-1})-0.00659t$

(2.718)* (-2.62)* (-2.18)*

R^2=0.143,F=4.28* ,DW=1.93 , *=significant at 5% level

Random walk with drift hypothesis of the inflation rate is seen in the Fig-2

Fig-2:Random walk with drift



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Assuming Bai-Perron test(2003) of L+1 vs.L sequential determined breaks selecting Trimming 0.15,maximum breaks 5 with 5% significant level,we found one downward break in 1992 following HAC standard errors and covariance and Newey-West fixed bandwidth=4.0.In Table-1,the significant values are given.

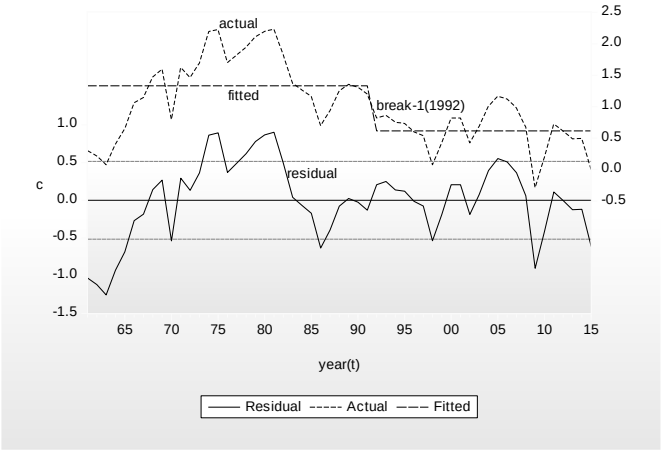
Table-1:Structural breaks

Variable	Coefficient	Std. Error	t-Statistic	Prob.
		1961 - 1991 -- 31 obs		
C	1.332382	0.193193	6.896640	0.0000
		1992 - 2015 -- 24 obs		
C	0.613795	0.089569	6.852735	0.0000
		R^2=0.33,F=26.21*DW=0.43		
Break test: Sequential F-statistic determined breaks:1				
Break Test	F-statistic	Scaled F-statistic	Critical Value**	
0 vs. 1 *	11.35600	11.35600	8.58	
1 vs. 2	8.554023	8.554023	10.13	

Source-Computed by author

In Fig-3,the fitted line and actual line were plotted where structural break is shown in 1992 which is downward.

Fig-3:Structural break



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The auto-regressive with lag one model of the inflation rate of USA from 1961 to 2015 is found stable, stationary and significant when estimated.

$Logx_t=0.8549+0.864logx_{t-1}+0.106\sigma^2$

(2.70)* (11.22)* (5.82)*

R^2=0.72 , F=67.9* , Inverted AR root=0.86 , *=significant at 5% level

One percent increase in inflation rate per year leads to 0.8828 percent decrease in growth rate of GDP per year in USA during 1961-2015 which is significant at 5% level.

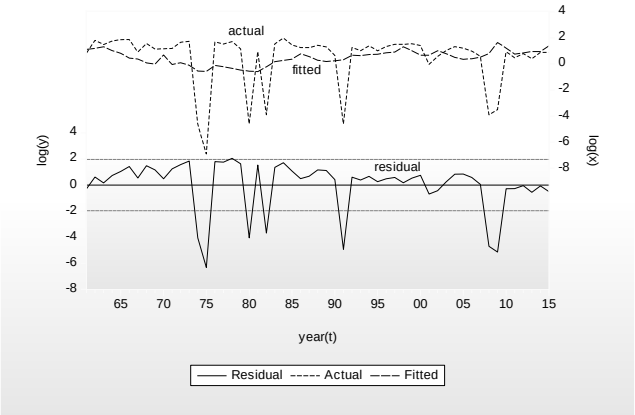
Log(y)=1.3857 -0.8828log(x)

(2.71)* (-2.05)*

R^2=0.074 ,F=4.24* ,DW=1.64 , *=significant at 5% level, y=GDP growth rate per year

In Fig-4,the fitted regression line is non-linear along with actual line are plotted below.

Fig-4:Growth-Inflation relation



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Granger-Causality test suggest that growth does not Granger cause inflation but inflation rate does Granger cause growth rate in USA during 1961-2015 ,ie, causality is uni-directional.In the Table- 2,the details are given.

Table- 2: Granger causality test

Null Hypothesis:	Obs	F-Statistic	Prob.
Y does not Granger Cause X	54	8.81726	0.0045
X does not Granger Cause Y		0.93764	0.3375

Source-Computed by author

Johansen unrestricted cointegration rank test with lag one proves that Trace Statistic and Max Eigen Statistic have one cointegrating equation each which is significant at 5% level that indicates that growth and inflation are cointegrated in the order one.In Table-3,their values are arranged.

Table-3:Johansen Cointegration

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.314471	22.25409	15.49471	0.0041

At most 1	0.041440	2.243138	3.841466	0.1342
Hypothesized No. of CE(s)	Eigenvalue	Max Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.314471	20.01095	14.26460	0.0055
At most 1	0.041440	2.243138	3.841466	0.1342

* denotes rejection of the hypothesis at the 0.05 level, **MacKinnon-Haug-Michelis (1999) p-values

Source-Computed by author

Since the inflation rate and GDP growth rate is cointegrated,then vector error correction model will show the equilibrium condition with the speed of error correction.The estimated VEC model is given below.

Δy_t=-0.0668-0.032054Δy_{t-1}-0.4503Δx_{t-1}-0.5512EC

(-0.29) (-0.21) (-2.14)* (-3.72)*

R^2=0.36,F=9.21* ,AIC =3.93 ,SC=4.08

Δx_t=-0.0041-0.1205Δy_{t-1}-0.0245Δx_{t-1}+0.3434EC

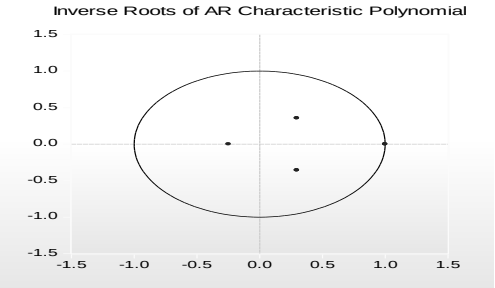
(-0.027) (-1.23) (-0.17) (3.5)*

R^2=0.21 , F=4.48* , AIC= 3.11, SC=3.26

Although VECM is a poor fit but both Δy_t and Δx_t have been marching towards equilibrium with correcting errors by 55% and 34% per year respectively which are significant.

Even, the VECM is a stable model because all the roots (1.0, 0.297753 ± 0.356572i , -0.247919) lie inside the unit root circle which is shown below.

Fig-5:Unit root circle



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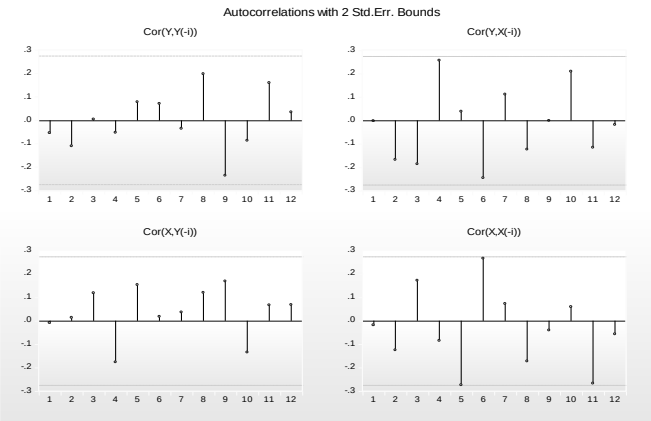
The residual test of the VECM assured that it has problem of autocorrelation which is shown in the Fig-6.

Fig-6:Problem of autocorrelation



Source-Computed by author

VEC residual serial correlation LM test showed that it has serial correlation which is arranged in the Table-4

Table-4:Values of LM stat and their probabilities.

Lags	LM-Stat	Prob
1	1.563415	0.8154
2	4.973703	0.2900
3	4.113636	0.3908
4	5.571221	0.2335
5	5.360493	0.2523
6	7.211407	0.1251
7	1.347350	0.8533
8	5.437101	0.2453
9	4.356749	0.3599
10	4.139272	0.3875
11	6.966177	0.1377
12	0.574638	0.9658

Source-Computed by author.

VEC residual normalitytest of Doornik-Hansen showed that Chi-square values of skewness are not significant, Chi-square value of component one of Kurtosis and component one of Jarque-Bera are not significant, therefore, the residuals are not multivariate normal.

Table-5:Normality test

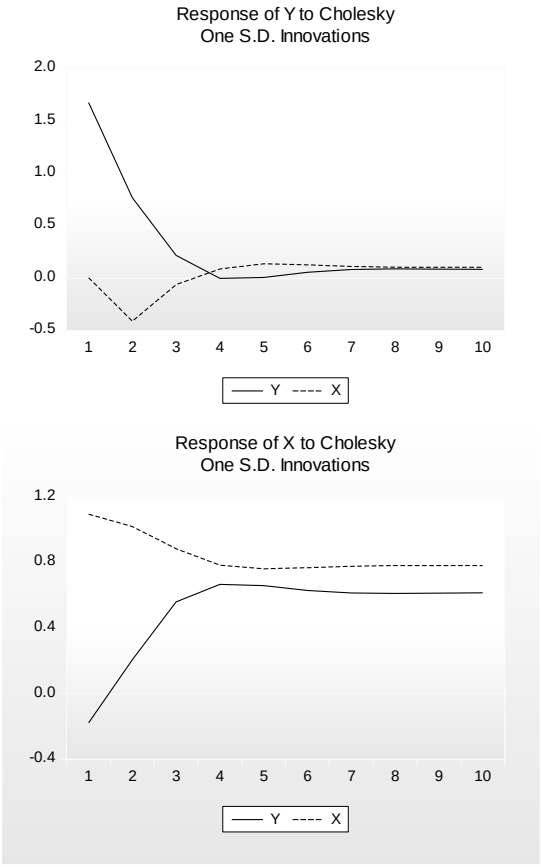
Component	Skewness	Chi-sq	df	Prob.
1	-0.197919	0.420527	1	0.5167
2	-0.149651	0.241777	1	0.6229
joint		0.662305	2	0.7181
Component	Kurtosis	Chi-sq	df	Prob.

1	2.600216	0.065477	1	0.7980
2	4.110174	6.005377	1	0.0143
joint		6.070853	2	0.0481
Component	Jarque-Bera	df	Prob.	
1	0.486004	2	0.7843	
2	6.247154	2	0.0440	
Joint	6.733158	4	0.1507	

Source-Computed by author

The impulse response functions under Cholesky S.D. innovation are diverging from equilibrium.

Fig-7:Impulse Response Functions



Source-Computed by Author

[A] Threshold level of inflation :Growth and GDP deflator

Assume $\log(y)=\beta_0+\beta_1\log(x)+\beta_2 D\log(x_{1j})+U_i$

Where D=Dummy variable and $x_{1j}=x-k_{1j}$ and D=1 if $x>k_{1j}$ and D=0 if $x\leq k_{1j}$,j=1…..4 and k_{1j}=threshold value of GDP deflator(x) at j.

β_0=constant,β_1=constant,β_2=constant which measure the effects of GDP deflator on economic growth when it is greater than the structural break levels.By estimating the regression for different values of k_{1j}(structural break levels),the optimum value of k_{1j} is obtained by finding the value that maximizes the $R^2$and minimizes the Sum Squares of Residuals (SSR)from the respective regression.

[i]AtK_{11}=1.75%,therefore the estimated regression becomes

$\text{Log}(y)=6.85-5.435\log(x)+1.66\log(x_{11})+u_i$

(2.79)* (-2.61)* (1.93)*

R^2=0.21,F=5.21* , Sum Square Residuals=155.85,*=significant at 6% level

[ii]AtK_{12}=2.0%,therefore,the estimated regression is

$\text{Log}(y)=5.10-3.53\log(x)+0.526\log(x_{12})+u_i$

(2.58)* (-2.4)* (1.14)

R^2=0.22 ,F=5.07* ,SSR=135.46 , *=significant at 5%

[iii]At 1992,k_{13}=2.27%,(structural break point)then the estimated regression is

Log(y)=8.7501-6.222log(x)+1.508log(x_{13})+u_i

(2.23)* (-2.07)* (1.24)

R^2=0.262 ,F=4.62* ,SSR=125.46 and *=significant at5% level.

[iv] At K_{14}=2.5%,then the estimated regression is

Log(y)=8.197-5.5095log(x)+0.997log(x_{14})+u_i

(2.18)* (-2.06)* (1.09)

R^2=0.257 ,F=4.32* ,SSR=125.91 ,*=significant at 5% level

[v] At k_{15}=3.0% ,then the estimated regression is

Log(y)=12.789-8.183log(x)+1.578log(x_{15})+u_i

(2.32)* (-2.29)* (1.51)

R^2=0.28, F=4.21* ,SSR= 116.77 , *=significant at 5% level

Thus, when the threshold level of GDP deflator=1.75%,the negative growth rate of GDP becomes maximum in USA where R^2 is maximum and coefficients of x and coefficient of x_{11} are significant and RSS is not minimum .At GDP deflator=2.27% where structural break exists, the coefficient of logx_{13} is not significant but other coefficients are significant at 5% level and SSR=125.46 and R^2 at 2.27%=0.26 which is not maximum but at 1.75% ,the R^2=0.21 and SSR=155.85 and all the coefficients are significant .But at 3.0%, the SSR is minimum and R^2 is maximum but coefficient of log(x) is not significant. Therefore it is justified to set a limit of 1.75-3.0 per cent at target level of inflation for USA beyond which the negative growth rate is maximum where structural break level is 2.27 percent.

Limitations and Future Scope of the Study

In USA, growth inflation nexus is negative during 1961-2015 and its threshold limit of inflation is 1.75-3.00 per cent beyond which the negative growth is more harmful for the country than the previous level but most of studies confer that the nexus is positive and after the threshold rate the growth would be negative. Unemployment rate can be included here for further clarification. Instead of GDP deflator the consumer price index and whole sale price index can be treated as inflation indicators.

Policy Recommendations

Federal Reserve Bank of USA generally proposes the following monetary and fiscal policy to curb the inflation rate, such as

[i]To conduct fixed exchange rate

[ii]To increase general level of money income (money wage rate) as a nominal anchor

[iii]To raise interest rate for raising deposit creation

[iv]To introduce currency reform to gain more confidence in monetary system

[v] To ensure real interest rate in both loan and deposit as positive

[vi]Federal Reserve Bank credit expansion should consistent with assets in determining monetary expansion consistent with inflation control

[vii]When the expected rate of inflation rises above the target rate the Federal Reserve Bank increases nominal interest rate to reduce demand and controls inflation

[viii] To introduce fiscal reform to cut fiscal deficit

[ix]To cut taxes to reduce spending so as to decrease demand

[x] To reduce government spending and transfer payment

[xi] To introduce contractionary fiscal policy at boom and introduce expansionary fiscal policy at recession.

Conclusion

The paper concludes that inflation of USA has been declining at the rate of 1.58% per year during 1961-2015.It has no random walk with drift but it showed a structural break in 1992 at 2.27% .One percent increase in inflation rate per year led to 0.88% decrease in growth rate per year in USA at the specified time.Growth inflation causality is unidirectional and they are cointegrated in the order one. Error correction is speedy and significant which was found in VECM which is stable but divergent. The threshold level of inflation rate or target rate is a limit of 1.75-3.00 per cent beyond which growth will be more adverse for the economy.

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