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RESEARCH ARTICLE

GROWTH-INFLATION NEXUS: THRESHOLD MODEL OF INFLATION IN INDIA

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ABSTRACT

In this paper, author tries to relate inflation rate (measured both by CPI and WPI) with growth rate in India during 1960-2015 and calculated target rate of WPI and CPI. Author used Bai-Perron test (2003) for structural breaks and also used Granger Causality test (1969), Johansen cointegration and vector error correction models (1991,1996) for relationship and used residual test for autocorrelation and found impulse response functions for convergence and stability for both CPI and WPI with growth. By taking Khan and Senhadi model (2001), author found out the target rate of CPI and WPI for India. Author observed that one per cent increase in whole sale price index per year leads to 0.59 per cent increase in GDP growth rate per year in India during 1960-2015. The WPI granger cause growth rate but not vice versa i.e. causality is uni-directional. Growth and WPI is cointegrated in the order of one. VEC Model is stable but change in WPI has slow error correction whereas change in growth rate is not a good fit but its error correction process is faster than change in WPI. Its residuals are not normal having autocorrelation problem and impulse response functions are diverging. During 1960-2015, WPI has four structural breaks at 1974, 1988, 1995 and 2008 respectively. Above the threshold level of WPI=4.12 with 2010=100, the inflation-growth nexus tends to negative. The paper also found that one per cent increase in consumer price index per year leads to 0.55 per cent increase in GDP growth rate per year in India during 1960-2015. The CPI granger cause growth rate but not vice versa i.e. causality is uni-directional. Growth and CPI is cointegrated in the order of one. VEC Model is stable and is highly good fit but only error correction process of change in growth rate is significant for speedy correction. Its residuals are not normal having autocorrelation problem and impulse response functions are diverging. During 1960-2015, CPI has four structural breaks at 1974, 1987, 1996, and 2008 respectively. Above the threshold level of CPI=3.258 with 2010=100, the inflation-growth nexus tends to negative.

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INTRODUCTION

The relationship between inflation and growth remains a controversial one in both theory and empirical findings. Fisher believed that investors and savers were afflicted in varying degrees by money illusion. In an ideal world, changes in the price level would have no effect on production or employment. In the actual world with money illusion, inflation (and deflation) did serious harm. For more than forty years, Fisher elaborated his vision of the damaging "dance of the dollar" and devised various schemes to "stabilize" money, i.e. to stabilize the price level. He was one of the first to subject macroeconomic data, including the money stock, interest rates, and the price level, to statistical analyses and tests. His 1926 paper on the statistical relation between unemployment and inflation, retitling it as "I discovered the Phillips curve" played an important role in monetary theory.

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During 1950s, the issue has generated an enduring debate between *structuralists* and *monetarists*. The structuralists believe that inflation is essential for economic growth, whereas the monetarists see inflation as detrimental to economic progress. The monetarism updated the quantity theory of money by reemphasizing the critical role of monetary growth in determining the rate of inflation, whereas neoclassical and endogenous growth theories sought to account for the effects of inflation on growth through its impact on investment and capital accumulation. Tobin (1965), who assumed money as substitute to capital, established the positive impact of inflation on growth, his result being known as the Tobin effect. The negative impact of inflation on growth, is also known as the anti-Tobin effect. Stockman (1981) proposes a model in which money is a complement to capital, so inflation generates negative effects on growth. Friedman's hypothesis that higher nominal inflation raises inflation uncertainty, has tended to investigate the relationships among inflation, inflation uncertainty, growth and growth uncertainty. The second line of research has tended to remain within the traditional

macroeconomics and investigate the relation between inflation and growth without reference to inflation uncertainty and growth uncertainty. The Real Business Cycle theories assert that inflation negatively affects growth. Phillips Curve models, which held that inflation and economic growth can be positively associated when inflationary pressures emerge as a byproduct of rising aggregate demand. In this Keynesian framework, it is not the case that inflation is itself a positive engine of growth, certainly not a primary growth-inducing force. Within this Keynesian framework, there could also be reasons for inflation and growth to be negatively correlated when inflation results from monopolistic pricing practices, exchange rate volatility or supply shocks. Fischer (1993), Barro (1995) and others showed negative relationship between growth and inflation .The non-linearity in the growth inflation relationship was explained by modern scholars with threshold inflation level following Fischer (1993) but there arise several questions which remain unsolved. The purpose of this paper is to find out the empirical relationship between growth and inflation taking WPI and CPI as the indicators in India during 1968-2015 showing the threshold level of WPI and CPI.

Literature Review

Raul Ibarra Danilo Trupkin (2011), Wang Zhiyong. (2008). Abis Getachew Makuria (2013), Khan and Senhadji (2001). Sarel (1996), Shamim Ahmed and Md. Golam Mortaza (2005), Cooray (2013), Hayat and Kalirajan, (2009). Munir et al. (2009). Le Thanh Tung and Pham Tien Thanh (2015), Vinayagathasan (2013) Seleteng, Bittencourt and Eyden (2013), Fakhri Hasanov (2011), Stephanie Kremer, Alexander Bick and Dieter Nautz (2011), Samir Ghazouani (2012), David Drukker, Pere Gomis-Porqueras and Paula Hernandez-Verme (2005), Henryk Gurgul and Łukasz Lach (2011), Pypko Sergii (2009), Berber and Artan (2004), Nicas Yabu and Nicholaus J. Kessy (2015) studied that the nexus between economic growth and inflation is positive but there must be threshold level of inflation above which the relationship is negative i.e. inflation above the threshold limit will harm growth. Alvan Ikoku (2015), Costin C. Kiriţescu (2011), Shailender Singh and Amar Singh (2015) Osuala, et al. (2013), Dr. Md. Elias Hossain, Bikash Chandra Ghoshand Md. Khairul Islam (2012), Girijasankar Mallik and Anis Chowdhury (2001), Dr.Kanchan Datta and Dr.Chandan Kumar Mukhopadhyay (2011), verified positive relation between growth and inflation rate. Fikirte Tsegaye Mamo (2012), Md. Shakhaowat Hossin (2013), Muhammad Ayyoub, Imran Sharif Chaudhry and Fatima Farooq (2011), Vikesh Gokal and Subrina Hanif (2004), Ayyoub, Chaudhry, and Farooq (2011), proved in their econometric studies that the nexus between growth and inflation is negative.

MATERIALS AND METHODS

To relate growth with inflation in India during 1960-2015,we take whole sale price index and consumer price index as the indicators for inflation. For growth we use GDP growth rate of India .Finding nexus between growth and WPI and CPI we use Granger Causality test (1987), Johansen cointegration test (1988), Johansen VEC model (1991, 1996) and other residual tests. To find out threshold level of inflation, we first use Bai-Perron test (2003) to get structural breaks and then we use threshold model of inflation in both WPI, and CPI following Khan and Senhadji (2001). The data of WPI, CPI and GDP growth of India from 1960 to 2015 have been collected from International Bank for Reconstruction and Development (World Bank).

Observations from the Econometric Models

Growth-Consumer price index nexus

Double log model of regression states that one per cent increase in consumer price index per year leads to 0.55 per cent increase in GDP growth rate per year in India during 1960-2015 which is significant at 5% level.

$$\text{Log}(y)=-0.4590+0.5573\log(x_1)+u_i$$
$$(-0.7749)\ \ (3.0)^*$$

R^2=0.143, F=9.01*, DW=1.89, where x_1=CPI with 2010=100, y=GDP growth rate

In Fig-1, the fitted line and the actual line are plotted on the basis of the estimate. The fitted line is shown upward.

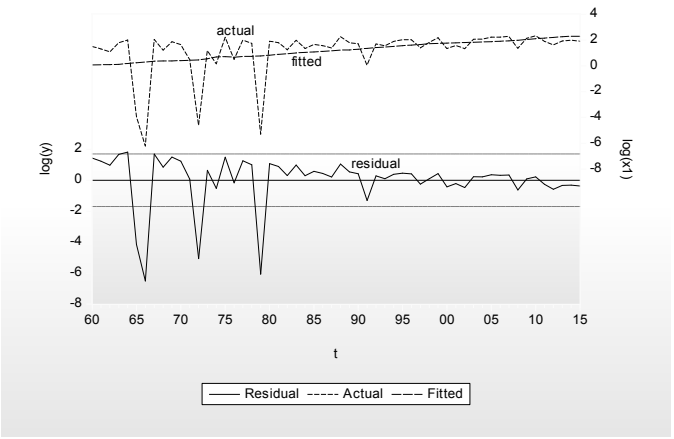


Fig. 1. Growth and consumer price index

Source-Computed by author

Consumer price index Granger cause GDP growth rate but opposite is not true which means GDP growth rate and CPI have uni-directional causality which is shown below.

Table 1. Causality between growth and CPI

Null Hypothesis:	Obs	F-Statistic	Prob.
Y does not Granger Cause X_1	55	0.15932	0.6914
X_1 does not Granger Cause Y		10.4171	0.0022

Source-Computed by author

Johansen cointegration rank test between GDP growth rate and consumer price index during 1960-2015 in India suggests that both the Trace statistic and Max Eigen Statistic verified one cointegrating equation at the 5% significant level which is shown below.

Table 2. Johansen cointegration rank test

Hypothesized No. of CE(s)	EigenValue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.409287	29.48768	15.49471	0.0002
At most 1	0.01945	1.06075	3.841466	0.3030
		Max Eigen Statistic		
None *	0.40928	28.42692	14.26460	0.0002
At most 1	0.01945	1.06075	3.841466	0.3030

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

Source-Computed by author

Since there is cointegration between growth and consumer price index in India during 1960-2015, therefore, we require VEC model for those variables for minimizing error correction process to attain stability. The estimates of the VECM are given below. Δx_{1t} is a good fit having very slow error correction process where as Δy_t is also a good fit but its error correction process is faster than Δx_{1t}.

Δx_{1t}=0.350649+0.842138Δx_{1t-1}-0.210166Δy_{t-1}-0.00844EC
(0.99) (9.21)* (-1.89)* (-1.24)
R^2=0.636, F=29.22* ,SC=4.39 , AIC=4.245
Δy_t= 0.43035-0.148677Δx_{1t-1}+0.09827Δy_{t-1}+0.04922EC
(0.935) (-1.24) (0.68) (5.55)*
R^2=0.534, F=19.12*, SC=4.92, AIC=4.77

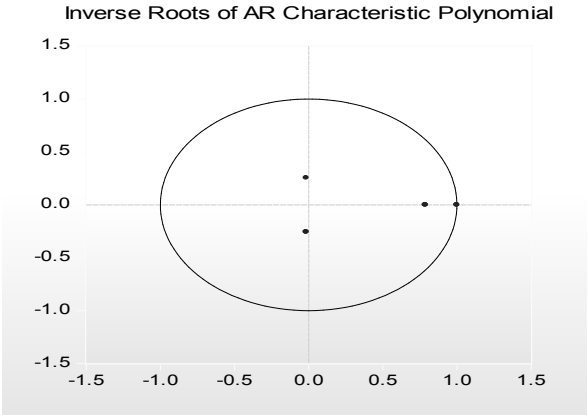
This VEC model has one unit root and other three roots are less than one which means they lie within the unit root circle i.e. the model is stable.

Table 3. Roots of Characteristic polynomial

Root	Modulus
1.000000	1.000000
0.786969	0.786969
-0.015588 - 0.255377i	0.255852
-0.015588 + 0.255377i	0.255852

Source-Computed by author

Fig. 2. Unit root circle



Source-Computed by author

Residuals of the VECM are not multivariate normal because Doornik-Hansen normality test assures that in the second component, skewness and kurtosis are insignificant at $\chi 2$ distribution and Jarque-Bera at second component is insignificant which are arranged in the Table-4.

Table 4. VEC residual normality test

Component	Skewness	Chi-sq	df	Prob.
1	-2.392174	28.10083	1	0.000
2	-0.146113	0.2342	1	0.6284
Joint		28.33503	2	0.000
Component	Kurtosis	Chi-sq	df	Prob.
1	16.74795	4.26177	1	0.039
2	2.049268	2.5403	1	0.111
Joint		6.802128	2	0.0333
Component	Jarque-Bera	df	Prob.	
1	32.36260	2	0.000	
2	2.774562	2	0.2498	
Joint	35.13716	4	0.000	

Source-Computed by author

Correlogram of the residuals confirmed that it suffers from autocorrelation problems too which is shown in the Figure- 3.

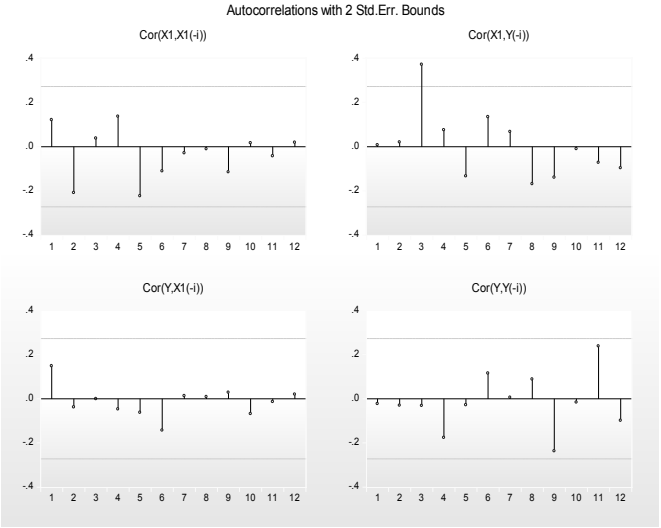
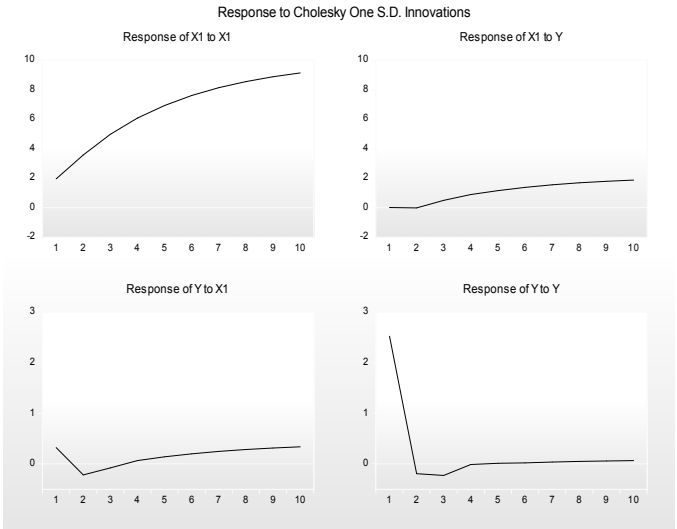


Fig. 3. Residual test of autocorrelation

Source-Computed by author

But VEC model is not stationary since ΔX_{1t} and ΔY_t do not converge to zero which means exogenous shock induced them from preventing to converge which is seen in the Fig-4 by impulse response functions.



Source-Computed by author

Figure 4. Impulse Response Functions of the VEC model

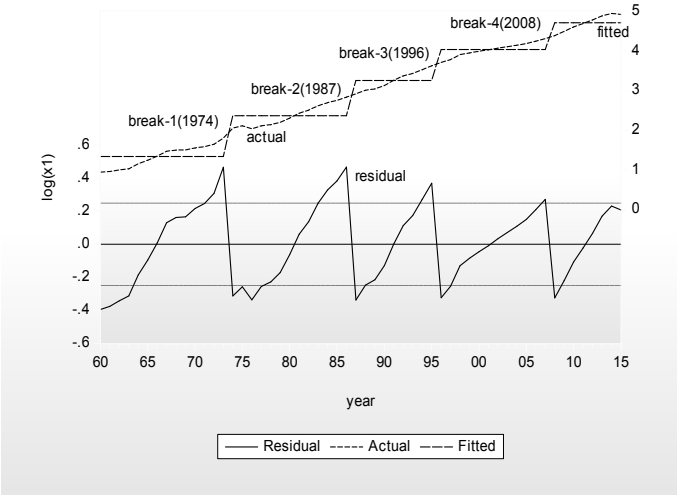
Threshold level of inflation model (1)

By applying Bai-Perron test (2003) of L+1 vs L sequentially determined structural breaks selecting trimming 0.15 with maximum 5 breaks on the basis of HAC standard errors and covariance, we have got four structural breaks in 1974,1987, 1996 and 2008 respectively in the series of consumer price index during 1960-2015 whose structural breaks are upward. They are arranged in the Table-5.In Fig-5, those structural breaks have been plotted clearly.

Table 5. Structural breaks in consumer price index

Variable	Coefficient	Std. Error	t-Statistic	Prob.
		1960 - 1973 -- 14 obs		
C	1.3422	0.131425	10.2171	0.0000
		1974 - 1986 -- 13 obs		
C	2.371754	0.137838	17.20679	0.0000
		1987 - 1995 -- 9 obs		
C	3.258914	0.126969	25.66705	0.0000
		1996 - 2007 -- 12obs		
C	4.036889	0.083212	48.5131	0.0000
		2008-2015—8obs		
C	4.712674	0.106312	44.32885	0.000

Source-Computed by author:R^2=0.962,F=323.92,DW=0.7621



Source-Computed by author

Fig. 5. Structural breaks in consumer price index

[A] Threshold level of inflation :Growth and CPI

Assume $\log(y)=\beta_0+\beta_1\log(x_1)+\beta_2 D\log(x_{1j})+U_i$

Where D=Dummy variable and $x_{1j}=x_1-k_{1j}$ and D=1 if $x_1>k_{1j}$ and D=0 if $x_1\leq k_{1j}$,j=1…..4 and k_{1j}=threshold value of CPI(x_1) at j.

β_0=constant, β_1=constant,β_2=constant which measure the effects of CPI 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 Residual Sum of Squares (RSS) from the respective regression.

[i]At 1974,K_{11}=1.34,therefore the estimated regression becomes

$\text{Log}(y)=-1.077048+1.782523\log(x_1)-1.07544\log(x_{11})+u_i$
(-0.752) (0.689) (-0.475)
R^2=0.148, F=4.55*, RSS=154.85

[ii]At 1987, K_{12}=2.37, therefore, the estimated regression is
$\text{Log}(y)=-1.344+1.37699\log(x_1)-0.599\log(x_{12})+u_i$
(-1.25) (1.62) (-0.98)
R^2=0.158, F=4.99*, RSS=152.69

[iii]At 1996, k_{13}=3.258, then the estimated regression is
$\text{Log}(y)=2.0213-2.133268\log(x_1)+2.11735\log(x_{13})+u_i$
(1.67) (-2.34)* (3.29)*
R^2=0.365, F=13.8*, RSS=114.41 and *=significant at 5% level.

[iv] At 2008,k_{14}=4.036, then the estimated regression is
$\text{Log}(y)=-0.6466+0.8619\log(x_1)-0.2617\log(x_{14})+u_i$
(-0.55) (1.146) (-0.531)

R^2=0.134, F=3.58*, RSS= 84.127, *=significant at 5% level
Thus, above the threshold level of CPI=3.258 with 2010=100, the growth rate of GDP becomes negative in India where R^2 is maximum and coefficients of x_1 and x_{14} are significant and RSS is minimum.

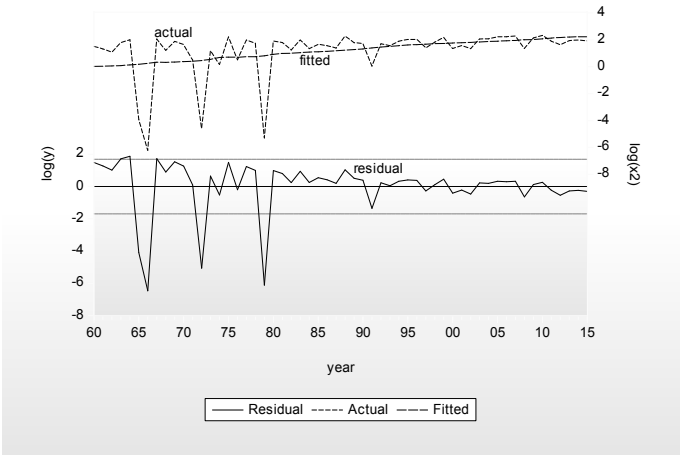
Growth-whole sale price index nexus

One per cent increase in whole sale index per year leads to 0.59 per cent increase in GDP growth rate per year in India during 1960-2015 which is significant at 5% level. The estimate is given below.

$\text{Log}(y)=-0.648016+0.59026\log(x_2)+u_i$
(-1.00) (3.028)*

R^2=0.145, F=9.17* , DW=1.89 where y= GDP growth rate, x_2= whole sale index with 2010=100, *=significant at 5% level

In Fig-6, both actual and fitted lines are plotted on the basis of the estimate. The fitted line moves marginally upward.



Source-Computed by author

Fig. 6. Growth and whole sale price index

Whole sale price index granger cause GDP growth rate but opposite is not true which means that GDP growth rate and WPI have uni-directional causality which is shown below.

Table 6. Causality between growth and WPI

Null Hypothesis:	Obs	F-Statistic	Prob.
Y does not Granger Cause X_2	55	0.25178	0.6179
X_2 does not Granger Cause Y		12.363	0.0009

Source-Computed by author

Similarly, Johansen cointegration rank test between GDP growth rate and whole sale price index during 1960-2015 in India showed that both the Trace Statistic and Max Eigen statistic have one cointegrating equation in each at 5% significant level which means they are cointegrated in the order of CI(1) which is tabulated below.

Table 7. Johansen cointegration test between growth and WPI

Hypothesized No. of CE(s)	EigenValue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.418581	30.01316	15.49471	0.0002
At most 1	0.013425	0.729854	3.841466	0.3929
		Max Eigen Statistic		
None *	0.418581	29.2833	14.26460	0.0001
At most 1	0.013425	0.729854	3.841466	0.3929

Source-Computed by author,*denotes rejection of the hypothesis at 0.05 level,**MacKinnon-Haug-Michelis (1999)p values.

Since GDP growth rate and the whole sale price index have cointegrated in the order of one then we have to verify the VECM of those variables. The estimates of the VECM is highly good fit but only error correction of Δy_t is significant for speedy correction all of which are given below.

$$\Delta x_{2t}=0.59219+0.72104\Delta x_{2t-1}-0.05749\Delta y_{t-1}+0.1568EC$$
$$(1.66)^* \quad (6.67)^* \quad (-0.555) \quad (1.02)$$

$R^2=0.472$, F=14.94*, AIC=4.11 ,SC=4.26

$$\Delta y_t=0.18825-0.0588\Delta x_{2t-1}+0.11748\Delta y_{t-1}-1.22769EC$$
$$(0.388) \quad (-0.398) \quad (0.831) \quad (-5.84)^*$$

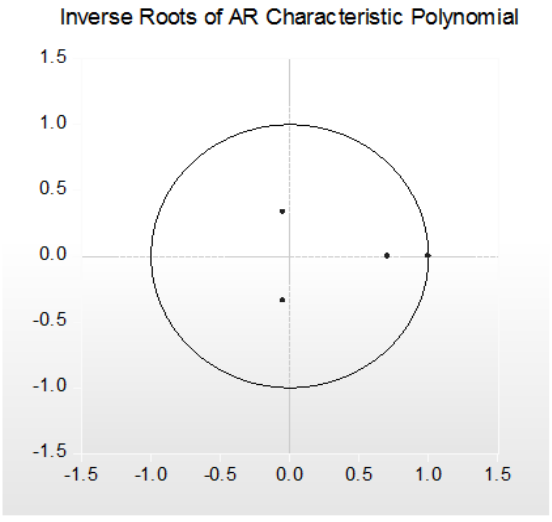
$R^2=0.552$, F=20.58*, SC=4.88, AIC=4.73,*=significant at 5% level

There is one unit root and all other three roots are less than one of the characteristic polynomials of the VECM which lie inside/on the unit root circle. Therefore the VECM is stable. In Table- 8, The values of the roots and in Fig-7, The unit root circle are given.

Table 8. Values of the roots

Root	Modulus
1.000000	1.000000
0.704340	0.704340
-0.049521 - 0.336182i	0.339809
-0.049521 - 0.336182i	0.339809

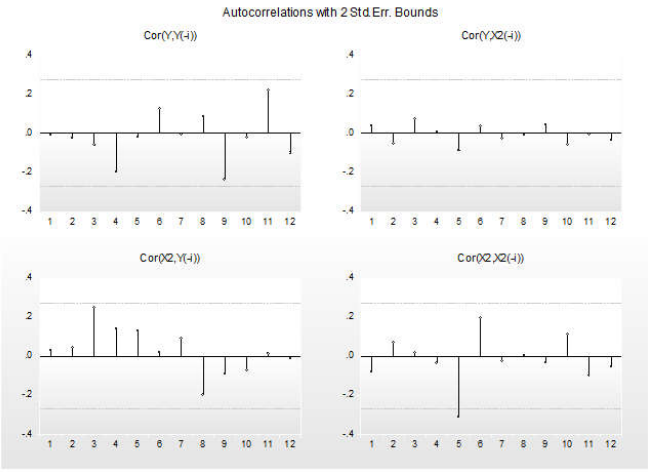
Source-Computed by author



Source-Computed by author

Fig. 7. Unit root circle of VECM between growth and WPI

Residual test confirmed that it has autocorrelation problem which is plotted in the Figure-8.



Source-Computed by author

Fig. 8. Autocorrelations

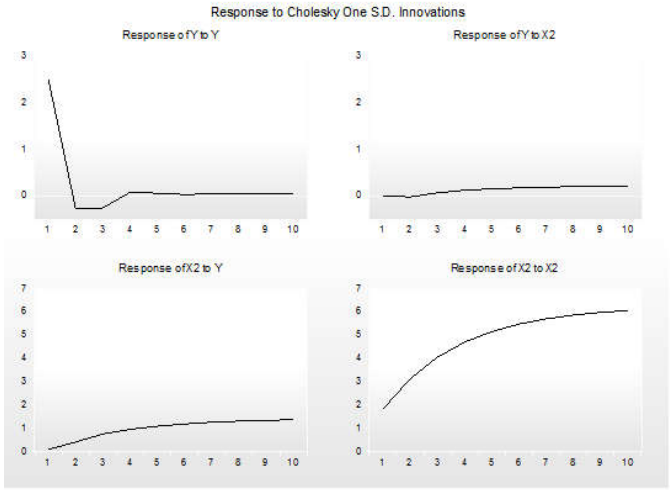
Doornik-Hansen normality test of the residuals showed that they are not multivariate normal which is given in the Table-9

Table 9. Normality test

Component	Skewness	Chi-sq	df	Prob.
1	-0.150958	0.249875	1	0.6172
2	-0.308805	1.020859	1	0.3123
Joint		1.270734	2	0.5297
Component	Kurtosis	Chi-sq	df	Prob.
1	2.050568	2.552991	1	0.1101
2	10.19585	65.15584	1	0.0000
Joint		67.70883	2	0.0000
Component	Jarque-Bera	df	Prob.	
1	2.802866	2	0.2462	
2	66.17669	2	0.000	
Joint	68.97956	4	0.000	

Source-Computed by author

But impulse response functions of the VECM state that Δx_{2t} and Δy_t are approaching away from zero ie diverging, so it is nonstationary and any external shock could not back the model into equilibrium which is shown in the Fig-9.



Source-Computed by author

Fig. 9. Impulse response functions of the VECM

Threshold level of inflation model (2)

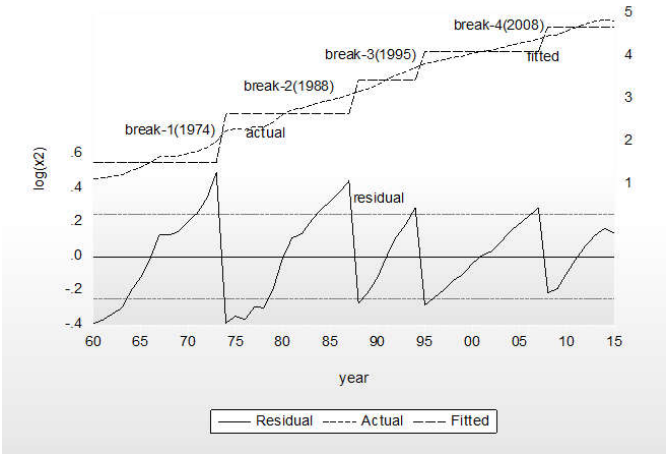
By applying Bai-Perron test (2003) of L+1 vs L sequentially determined structural breaks selecting trimming 0.15 with maximum 5 breaks on the basis of HAC standard errors and

covariance, we have got four structural breaks in 1974,1988, 1995 and 2008 respectively in the series of whole sale price index during 1960-2015 whose structural breaks are upward. They are arranged in the Table- 10.

Table 10. Structural breaks in whole sale price index

Variable	Coefficient	Std. Error	t-Statistic	Prob.
		1960 - 1973 -- 14 obs		
C	1.522455	0.13257	11.483	0.0000
		1974 - 19876 -- 14 obs		
C	2.654712	0.144611	18.3576	0.0000
		1988 - 1994 -- 7 obs		
C	3.45699	0.109388	31.60298	0.0000
		1995 - 2007 -- 13 obs		
C	4.118748	0.08782	46.8999	0.0000
		2008 - 2015 -- 8 obs		
C	4.70045	0.078376	59.9734	0.0000

Source-Computed by author;R^2=0.9586,F=295.54*,DW=0.6896



Source-Computed by author

Fig. 10. Structural breaks in whole sale price index

Threshold level of inflation :Growth and WPI

Assume $\log(y)=\alpha_0+\alpha_1\log(x_2)+\alpha_2 D\log(x_{2j})+U_i$

Where D=Dummy variable and $x_{2j}=x_2-k_{2j}$ where k_{2j}=constant value of structural break at j of k_2 (WPI=x_2) and D=1 if $x_2>k_{2j}$ and D=0 if $x_2\leq k_{2j}$, j=1…….4

α_2 measures the effects of WPI on economic growth when it is greater than the structural break level. Where $x_{2j}=x_2-k_{2j}$ and k_{2j}=constant value of structural break at j of k_2(WPI)

The following are the estimates.

[i]At 1974, k_{21}=1.52, the estimated regression is
$\text{Log}(y)=-1.5598+2.3775\log(x_2)-1.5705\log(x_{21})+u_i$
(-0.956) (0.809) (-0.609)
R^2=0.151, F=4.71*, RSS=154.057

[ii]At 1988,k_{22}=2.65,the estimated regression is
$\text{Log}(y)=-1.7475+1.66249\log(x_2)-0.8051\log(x_{22})+u_i$
(-1.34) (1.49) (-0.978)
R^2=0.160, F=5.06*, RSS=152.38

[iii]At 1995, k_{23}=3.45, the estimated regression is
$\text{Log}(y)=-0.2428-0.216379\log(x_2)+0.727838\log(x_{23})+u_i$
(-0.169) (-0.197) (0.931)
R^2=0.215, F=6.719*, RSS=142.018

[iv] At 2008, k_{24}=4.12,thus the regression is
$\log(y)=1.66609-1.603591\log(x_2)+1.66529\log(x_{24})+u_i$
(1.102) (-1.469) (2.189)*

R^2=0.2599, F=8.25*, RSS=114.05, *=significant at 5% level
Thus, above the threshold level of WPI(x_2)=4.12 with 2010=100, the growth rate of GDP in India tends to negative where R^2 is maximum, RSS is minimum and coefficient of x_{24} is significant.

Policy Implications

Threshold model of inflation and growth has important policy implications too. Policy makers can choose inflation target from which monetary and fiscal policy can be adopted along with selection of other macro fundamentals. In our model, Indian policy makers should control whole sale price index above 4.12 with 2010=100 or consumer price index above 3.258 with 2010=100 otherwise growth –inflation nexus must be negative above those threshold limits.

Limitations and Future Scope

This model is limited to bi-variate studies with one period lag which can be extended to multi-variate with two or three period lags. We can take international oil price, gold price, share price index, population growth, foreign direct investment, money supply, exchange rate, interest rate, terms of trade, and degree of openness as other variables which may affect inflation and growth too.

Conclusion

The paper concludes that one per cent increase in whole sale price index per year leads to 0.59 per cent increase in GDP growth rate per year in India during 1960-2015.The WPI granger cause growth rate but not vice versa i.e. causality is uni-directional. Growth and WPI is cointegrated in the order of one. VEC Model is stable but change in WPI has slow error correction whereas change in growth rate is not a good fit but its error correction process is faster than change in WPI. Its residuals are not normally distributed having autocorrelation problem and impulse response functions are diverging. During 1960-2015, WPI has four structural breaks at 1974,1988 ,1995 and 2008 respectively. Above the threshold level of WPI=4.12 with 2010=100, the inflation-growth nexus tends to negative.
The paper also concludes that one per cent increase in consumer price index per year leads to 0.55 per cent increase in GDP growth rate per year in India during 1960-2015. The CPI granger cause growth rate but not vice versa i.e. causality is uni-directional. Growth and CPI is cointegrated in the order of one. VEC Model is stable and is highly good fit but only error correction process of change in growth rate is significant for speedy error correction. Its residuals are not normally distributed having autocorrelation problem and impulse response functions are diverging. During 1960-2015 , CPI has four structural breaks at 1974,1987,1996,and 2008 respectively. Above the threshold level of CPI=3.258 with 2010=100, the inflation-growth nexus tends to negative.

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