Chapter-4

Techniques of Analysis and Interpretation of Results

To estimate the equation of the modern extended Phillips curve through regression technique, the times data on inflation rate, lagged inflation rate, output gap ratio and gap of output growth rates. But while regressing a time series variable on another time series variables one often gets very high R^2 and significant coefficient estimates even when there is no meaningful relationship between the variables. Sometimes we do not expect any relationship between variables, yet a regression of one on the other variables shows a significant relationship. This situation is indicative of a problem of spurious or non-sense regression. It is therefore very important to find out if the relation between economic variables in spurious or nonsensical. The regression analysis assumes that the underling time series are stationary and have no unit roots. A test of stationarity(for non-stationarity) that has become widely popular in the unit root test.

4.1 Unit Root Test

Augmented Dicky-Fuller Test

In this paper, we employ the Augmented Dicky-Fuller (ADF) test to test the stationarity of the four time series, namely,Infl, $Infl_{-1}$, (y – y*) / y* and (Gy – Gy*).

As can be seen from the figure 4.1 and 4.2, the four series appear to be stationary in the level form. However, we carry a rigorous test of ADF to these series. The ADF test is conducted by estimating the following three models. In the present study, however, only last two i.e., equation (2) and (3) have been utilized.

No intercept no trend model

$$\Delta y_t = \gamma\, y_{t-1} + \sum_{i=1}^{u} \beta_i \Delta y_{t-i} + \varepsilon_t \qquad \text{....(1)}$$

Intercept no-trend model

$$\Delta y_t = \alpha_0 + \gamma\, y_{t-1} + \sum_{i=1}^{u} \beta_i \Delta y_{t-i} + \varepsilon_t \qquad \text{....(2)}$$

Intercept& trend model

$$\Delta y_t = \alpha_0 + \alpha_1 t + \gamma y_{t-1} + \sum_{i=1}^{u} \beta_i \Delta y_{t-i} + \varepsilon_t \qquad \ldots.(3)$$

where $\Delta y_t = y_t + y_{t-1}$, is the first difference of the series y_t, $\Delta y_{t-1} = y_{t-1} + y_{t-2}$ is the first difference of y_{t-1} series etc. α & β are the parameters to be tested, ε_t is a stochastic disturbance terms. The difference between three equations, (1) to (3) is the exclusion or inclusion of the deterministic elements α_0 and α_1 equation (1) does not include the drift α_0 and time trend $\alpha_1 t$, equation (2) includes α_0 but no time trend and equation (3) includes both $\alpha_0 \& \alpha_1 t$. For carrying out the unit root test in the present study, however, we have confined ourselves to the last two models only.

In all cases the null hypothesis is,$\gamma=0$, the ADF test statistic is the t statistic for the lagged dependent variable. If the ADF statistical value is less than the critical value, then the null hypothesis of a unit root is rejected and conclude that y_t series is a stationary and the order of integration is zero,I(0). The computed values of ADF statistics along with their corresponding critical values pertaining to two models are reported in table (4.1).

The table 4.1 shows that computed value of the ADF statistic (-3.36) is less than the critical value (-2.92) at 5 percent level of significance. Therefore the null hypothesis that the time series Infl(GNPD) is non-stationary or has a unit root is rejected at 5 percent level of significance. It implies that the series Infl(GNPD) is stationary. Similarly, in case of the model with trend and intercept the null hypothesis that the series on Infl(GNPD) is not stationary or has a unit root is rejected at 10 percent level of significance as the computed value of ADF statistic (-3.01) is less than the critical value(-3.18). Therefore, Infl(GNPD) is stationary.

In case of $Infl_{-1}$(GNPD), the ADF statistic value (-5.69) is less than the critical value (-3.56) for intercept model and ADF statistic (-9.04) is less than the corresponding critical value (-4.14) for the intercept and trend model which means the null hypothesis that the time series $Infl_{-1}$(GNPD) is non-stationary or has a unit root is rejected at 1 percent level of significance on the basis of both the models.

Similarly, in case of a series of output gap ratio, $((y_t - y_t^*)/y_t^*)$, the table shows that the ADF statistic value (-29.74) is less than the corresponding critical value (-3.56) in case of intercept model, and value of ADF statistic (-56.55) is less than the corresponding critical value (-4.14) in case of time trend and intercept model. These values imply that the null hypothesis about time series on output gap ratio being non-stationary or having a unit root rejected at 11 percent level of significance.

As far as, the time series on the gap of output growth rates, (G_y-G_y*) is concerned the value of ADF test statistic (-3.37) is less than the corresponding critical value (-2.92) in case of intercept model which implies that the null hypothesis of no stationarity is rejected at 5 percent level of significance. Similarly, on the basis of intercept and trend model, the hypothesis of no stationarity or of having a unit root is rejected at 10 percent level of significance as the value of ADF statistic (-3.01) is less than the corresponding critical value (-3.18) at 10 percent level of significance. Thus, all the variables (in level) are stationary on the basis of ADF test at either one, five or ten percent level of significance. All the time series are stationary at first difference.

Table: 4.1

Augmented Dickey-Fuller Unit Root Test Results

Variables	Model	Level	First Difference
Infl(GNPD)	Intercept	-3.3561**	-6.1534*
		(-2.9178)	(-3.5625)
	Trend & Intercept	-3.0087***	-6.2317*
		(-3.1772)	(-4.1458)
Infl(GNPD) $_{-1}$	Intercept	-5.6877*	-5.4957*
		(-3.5598)	(-3.5625)
	Trend & Intercept	-9.0367*	-6.4307*
		(-4.1420)	(-4.1458)
Output Gap Ratio $((y_t - y_t^*)/ y_t^*)$	Intercept	-29.7438*	-27.7016*
		(-3.5598)	(-3.5625)
	Trend & Intercept	-56.5468*	-29.9754*
		(-4.1420)	(-4.1458)
Gap of output Growth Rates (Gy-Gy*)	Intercept	-3.3724**	-6.0806*
		(-2.9190)	(-3.5653)
	Trend & Intercept	-3.0132***	-6.1648*
		(-3.1782)	(-4.1498)

Note: (i) The figures are the values of ADF test statistic and the brackets contain thecritical values.

(ii)* significant at 1 percent level

(iii)** significant at 5 percent level

(iv)*** significant at 10 percent level

Phillips-Parron Test

The test regression for Phillips-Parron(PP) test in the AR(1) process

$\Delta y_{t-1}=\alpha_0 + \beta y_{t-1} + \varepsilon_t$

while ADF test corrects for higher order serial correlation by adding lagged differenced terms on the right hand side, the PP test makes a correction to the t statistic of the coefficient γ from AR(1) regression to account for the serial correlation in $\varepsilon_{t.}$ So the PP statistics is just modification of ADF-t statistics. The asymptotic distribution of the PP-t statistic is the same as the ADF, t statistics and therefore the same critical values are still applicable as with the ADF test. The PP test can be performed with inclusion of a constant, a constant and a linear trend or neither in the test regression. In the present study the PP test has been performed by including an intercept, and intercept and time trend only. i.e.

$\Delta y_{t-1}=\alpha_0 + \beta y_{t-1} + \varepsilon_{1t}$

$\Delta y_{t-1}=\alpha_0 + \alpha_{1t} + \beta y_{t-1} + \varepsilon_{2t}$

The PP-test is performed by testing the hypothesis of no stationarity (H_0:β=0) against the hypothesis that the series is integrated of order zero I(0) hence stationary. The computed PP statistics and corresponding critical values are given in table (4.2). If the computed values of PP-statistic is less than the corresponding critical value, then the null hypothesis of no stationarity is rejected and hence the series is stationary. The computed values of PP-statistics and their corresponding critical values pertaining to the two models have been shown in table (4.2). The table shows that all the four series were also tested for their unit roots with help of Phillips-Parron test. Parron test was conducted for two models i.e. intercept model as well as intercept and trend model. The series were tested both at level and at first difference both.

The time series on Infl(GNPD) was found to be stationary as the PP value (-4.63) is less than the corresponding critical value (-3.55) at 1 percent level of significance as the null hypothesis of non stationarity was rejected in case of intercept model.

Similarly, in case of intercept and trend model the null hypothesis of presence of unit root test was rejected as the PP value (-4.75) is less than the corresponding critical value(-4.13) at 1 percent level of significance.

Regarding the time series of lagged inflation, the null hypothesis of non stationarity was rejected in the context of both the models, the intercept model with PP value (-7.40) being less than critical value (-3.55), and the intercept and trend model with PP value (-7.59) being less than the critical value (-4.13).

Regarding the time series of output gap ratio, the estimates of intercept model show that the null hypothesis of no unit root is rejected at 1 percent level of significance as the PP value(-7.41) is less than the critical value (-3.55). Similarly the estimates of trend and intercept model as shown in the table reveal that the null hypothesis of no unit root is rejected at 1 percent level of significance as the PP value (-7.43) is less than the critical value (-4.13) at 1 percent level of significance. Therefore, on the basis of the Phillips-Parron test the time series of output gap ratio is stationary at levels.

Regarding the time series of gap of output growth rates, the PP value (-4.595) is less than the critical value (-3.55) in the context of intercept model. This implies that the null hypothesis of no stationarity is rejected at 1 percent level of significance. In case of trend and intercept model also, the PP value (-4.74) is less than the critical value (-4.13) at 1 percent level of significance. Therefore the hypothesis of presence of unit root is rejected at 1 percent level of significance. Thus, all the four time series are stationary on the basis of Phillips-Parron test on the basis of the two specifications with intercept only model as well as with trend and intercept model at their levels. Obviously, when the series are stationary at levels, they must be stationary in their first difference is shown in the tables.

The graphs of the four time series in their level as well as first difference have been shown in figure (4.1) and (4.2) respectively. The stationarity of these series is also seen from these figures.

Table: 4.2

Phillips-Parron Unit Root Test Results

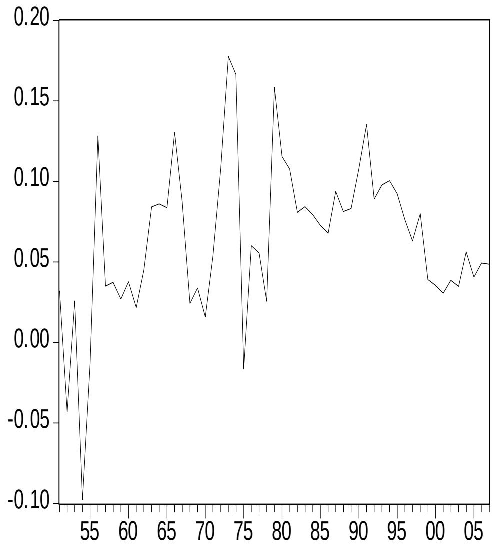
Variables	Model	Level	First Difference
Infl.(GNPD)	Intercept	-4.6325*	-11.2496*
		(-3.5501)	(-3.5523)
	Trend & Intercept	-4.7514*	-11.3510*
		(-4.1281)	(-4.1314)
Infl(GNPD) $_{-1}$	Intercept	-7.3975*	-17.0502*
		(-3.5501)	(-3.5523)
	Trend & Intercept	-7.5947*	-16.9423*
		(-4.1281)	(-4.1314)
Output Gap Ratio $((y_t - y_t^*)/ y_t^*)$	Intercept	-7.4062*	-16.5800*
		(-3.5501)	(-3.5523)
	Trend & Intercept	-7.4313*	-16.4482*
		(-4.1281)	(-4.1314)
Gap of output Growth Rates (Gy-Gy*)	Intercept	-4.5954*	-11.1390*
		(-3.5523)	(-3.5547)
	Trend & Intercept	-4.7397*	-11.2520*
		(-4.1314)	(-4.1348)

Note: (i) The figures are the Phillips-Parron statistic values and the brackets contain the critical values.

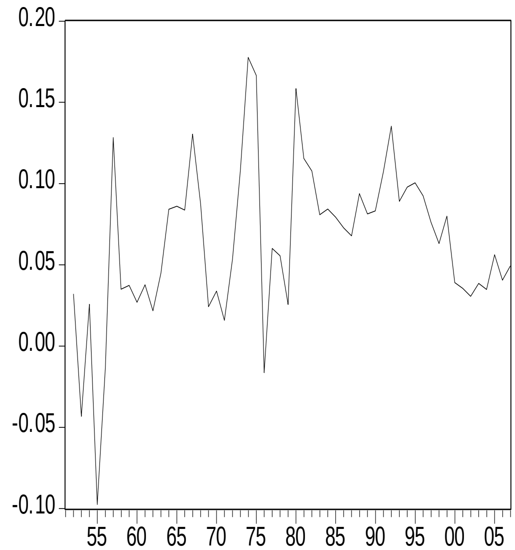
(ii) * indicates significance at 1 percent level.

Figure 4.1

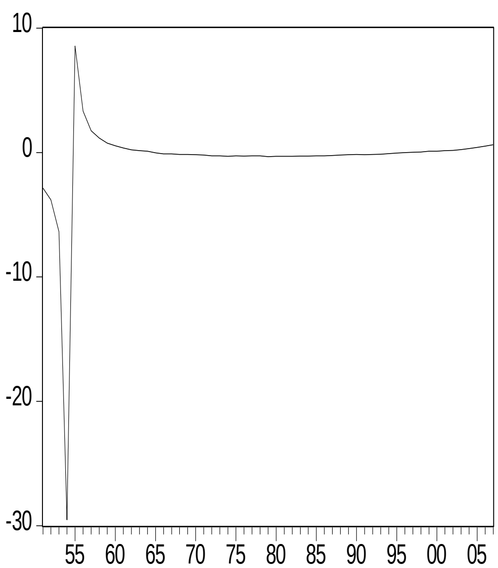
Graphs of Time Series (1951-52 to 2007-08) (in Level)

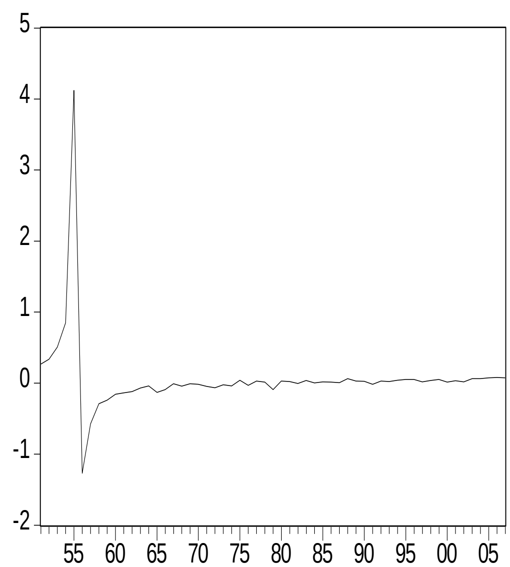


Infl(GNPD)



Infl(GNPD)$_{-1}$

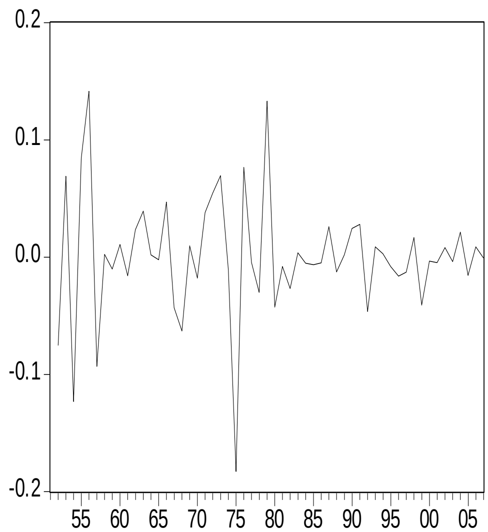




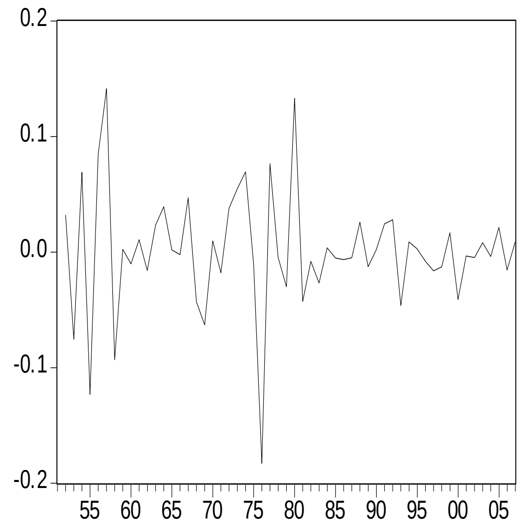
Output Gap Ratio $((y_t-y_t^*)/ y_t^*)$ Output Growth Gap (Gy-Gy*)

Figure 4.2

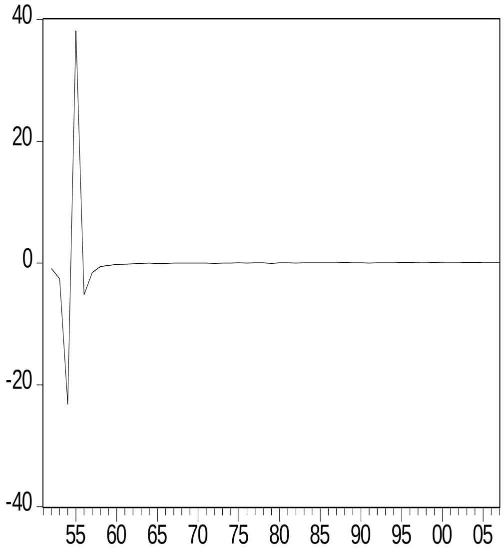
Graphs of Time Series (1951-52 to 2007-08)(in 1st Difference)



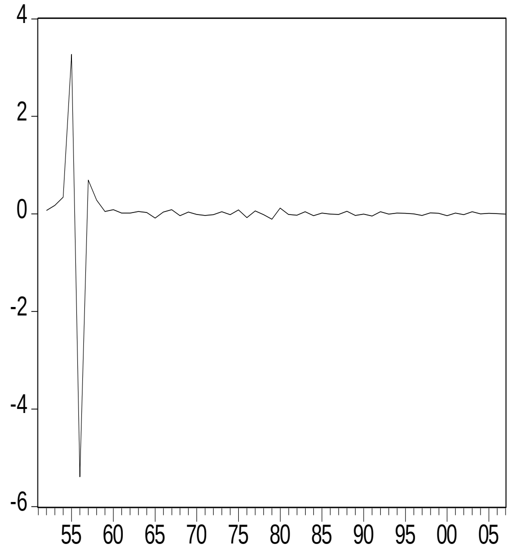
Infl(GNPD)



$Infl(GNPD)_{-1}$



Output Gap Ratio $((y_t - y_t^*)/ y_t^*)$



Output Growth Gap (Gy-Gy*)

4.2 Estimates of Phillips curve and their interpretation

Equation (9) represents our basic equation for the expectations augmented Phillips curve. The stochastic version of equation (9) to be estimated empirically would be:

$$\text{Infl (GNPD)} = \beta_0 + \beta_1 \text{Infl(GNPD)}_{-1} + \beta_2((y - y^*)/y^*) + \beta_3(G_y - G_{y^*}) + u \quad \text{….(10)}$$

where β_0 and β_i 's are parameters and u is the random error term with the usual OLS assumptions .

Regarding data source and construction of variables, we have used the Indian annual data for the period 1951-52 to 2007-08 for estimating the equation (10). Regarding rate of inflation, the rate of change in GNP Deflator has been used as a measure of inflation. The GNP deflator was obtained by dividing the GNP figures at current prices by those at constant prices. Gross National Product (GNP) at constant prices of the year 1999-2000 has been used as a measure of output. All the growth rates in prices and output are annual rates based on continuous compounding. The output gap is measured as a difference between actual output and trend value of output obtained by fitting the linear time trend of the GNP at (1999-2000) prices. The data on GNP deflator and Gross National Product (GNP) have been shown in table (4.3). The variables representing the inflation rate (Infl(GNPD)), output gap ratio ((y-y*)/y*) and gap of output growth rates (Gy-Gy*) are derived from table (4.3) and are presented in table (4.4).The OLS estimates of equation (10) along with their standard errors and t-values are given in table (4.5).

Table: 4.3

GNP Deflator and Output

Year	GNP DEFLATOR	OUTPUT (Y)
1951-52	4.4077	242441
1952-53	4.2167	248937
1953-54	4.3250	264349
1954-55	3.9027	276862
1955-56	3.8510	286160
1956-57	4.3450	302024
1957-58	4.4969	300563
1958-59	4.6650	322637
1959-60	4.7911	330570
1960-61	4.9718	348665
1961-62	5.0799	361170
1962-63	5.3081	371468
1963-64	5.7549	393789
1964-65	6.2501	422682

1965-66	6.7733	411203
1966-67	7.6572	411132
1967-68	8.3262	442877
1968-69	8.5282	458113
1969-70	8.8161	488049
1970-71	8.9553	513270
1971-72	9.4354	521779
1972-73	10.4561	519207
1973-74	12.3128	536865
1974-75	14.3643	543954
1975-76	14.1290	594281
1976-77	14.9783	604326
1977-78	15.8114	648663
1978-79	16.2153	685864
1979-80	18.7837	651138
1980-81	20.9554	695359
1981-82	23.2114	736039
1982-83	25.0877	759038
1983-84	27.2059	814313
1984-85	29.3640	844040
1985-86	31.5022	888512

Contd…

Table: 4.3 continued

Year	GNP DEFLATOR	OUTPUT (Y)
1986-87	33.6388	930506
1987-88	36.7950	965462
1988-89	39.7851	1055760
1989-90	43.0920	1118427
1990-91	47.7239	1177772
1991-92	54.1846	1189732
1992-93	59.0079	1255672
1993-94	64.7815	1317853
1994-95	71.2968	1406348
1995-96	77.8906	1512800
1996-97	83.8232	1629066
1997-98	89.1238	1698708
1998-99	96.2481	1803912

1999-00	100.0001	1936604
2000-01	103.5502	2008283
2001-02	106.7267	2116512
2002-03	110.8493	2199266
2003-04	114.7147	2383227
2004-05	121.1568	2580980
2005-06	126.0719	2824282
2006-07	132.2912	3098767
2007-08	138.7174	3387863

Source:- Ministry of Labour, Ministry of Commerce and Industry, Handbook of Industrial Policy and Statistics 2007-08 for WPI figures. GNP figures at constant prices have been taken from Handbook of Statistics on Indian Economy, RBI.

Table: 4.4

Infl(GNPD), Output Gap Ratio and Gap of output Growth Rates

Years	Infl(GNPD)	Output Gap Ratio	Gap of Output Growth Rates
1951-52	3.2055	-2.8846	0.2665
1952-53	-4.3320	-3.7972	0.3350
1953-54	2.5668	-6.3569	0.5074
1954-55	-9.7642	-29.5444	0.8508
1955-56	-1.3241	8.5551	4.1213
1956-57	12.8285	3.3396	-1.2684
1957-58	3.4954	1.7513	-0.5745
1958-59	3.7382	1.1669	-0.2895

1959-60	2.7036	0.7533	-0.2417
1960-61	3.7716	0.5280	-0.1556
1961-62	2.1734	0.3485	-0.1379
1962-63	4.4932	0.2081	-0.1195
1963-64	8.4160	0.1344	-0.0689
1964-65	8.6054	0.0928	-0.0408
1965-66	8.3712	-0.0357	-0.1297
1966-67	13.0491	-0.1179	-0.0931
1967-68	8.7381	-0.1243	-0.0079
1968-69	2.4261	-0.1600	-0.0440
1969-70	3.3756	-0.1658	-0.0074
1970-71	1.5790	-0.1783	-0.0161
1971-72	5.3609	-0.2146	-0.0469
1972-73	10.8180	-0.2625	-0.0646
1973-74	17.7565	-0.2780	-0.0223
1974-75	16.6614	-0.3055	-0.0401
1975-76	-1.6378	-0.2778	0.0419
1976-77	6.0113	-0.2994	-0.0313
1977-78	5.5621	-0.2810	0.0274
1978-79	2.5543	-0.2718	0.0134
1979-80	15.8394	-0.3366	-0.0927
1980-81	11.5612	-0.3190	0.0275
1981-82	10.7659	-0.3061	0.0197
1982-83	8.0834	-0.3102	-0.0061
1983-84	8.4432	-0.2857	0.0368
1984-85	7.9326	-0.2846	0.0017
1985-86	7.2817	-0.2713	0.0191
1986-87	6.7823	-0.2609	0.0147

Contd…

Table: 4.4 continued

Years	Infl(GNPD)	Output Gap Ratio	Gap of Output Growth Rates
1987-88	9.3827	-0.2566	0.0061
1988-89	8.1263	-0.2111	0.0630
1989-90	8.3120	-0.1884	0.0297
1990-91	10.7488	-0.1692	0.0243
1991-92	13.5377	-0.1836	-0.0178

1992-93	8.9016	-0.1612	0.0282
1993-94	9.7844	-0.1423	0.0230
1994-95	10.0573	-0.1078	0.0413
1995-96	9.2484	-0.0638	0.0505
1996-97	7.6166	-0.0160	0.0523
1997-98	6.3236	0.0021	0.0188
1998-99	7.9937	0.0398	0.0385
1999-00	3.8982	0.0914	0.0507
2000-01	3.5501	0.1070	0.0147
2001-02	3.0676	0.1417	0.0320
2002-03	3.8627	0.1615	0.0177
2003-04	3.4871	0.2329	0.0627
2004-05	5.6157	0.3084	0.0625
2005-06	4.0569	0.4035	0.0742
2006-07	4.9331	0.5101	0.0775
2007-08	4.8576	0.6197	0.0740

Source:**-** Derived from information contained in table (4.3) as explained in section 4.2.

Table: 4.5

OLS Estimates of equation of augmented Phillips curve (1951-52 to 2007-08)

Dependent Variable:- Infl(GNPD)

Variables	Coefficient	STD Error	T-Statistics
Infl (GNPD) $_{-1}$	0.3365*	0.1185	2.839
$((y - y^*)/y^*)$	0.0046*	0.0012	3.7027
$(G_y - G_{y^*})$	-0.0179**	0.0096	-1.8649
Intercept	0.0462*	0.0095	4.8674
R-Squared	0.587		
Adjusted R-Squared	0.5312		
D.W. Statistics	1.7473		

Note:- The lower and upper limits of D-W statistics for 3 explanatory variables are : dL=1.480, dU=1.689. * significant at 1 percent level. ** significant at 10 percent level

The estimate of the coefficient of the expected rate of inflation β_1 is positive and significant. The numerical value of this coefficient is important because in the long run , even with adaptive expectations, it is found that actual rate of inflation and expected rate of inflation are equal if the value of β_1 is one. But the result suggests that the estimate of β_1=.3365 is significantly different from zero. It is also significantly different from 1. This suggests that there is a short run Phillips curve in India and there no evidence of long run Phillips curve to be vertical. The price or wage rates are not sticky and that there is a trade-off between inflation and unemployment.

Another import result is regarding the estimated value of β_2.β_2 represents the sensitivity of wages/prices to the labour market disequilibrium. Its value is positive and significantly different from zero rejecting the null hypothesis β_1=0 at 1 percent level of significance. Since it represents the degree of responsiveness of wage to the disequilibrium in the labour market, it determines the slope of simple Phillips cure and aggregate supply curve. The wages and prices are not rigid and that there is a short run Phillips curve and there is a trade-off between inflation and unemployment.

The wages and prices are not rigid unlike Keynesian case. But the fiscal and monetary policies are lively to have significant effects on the level of output and employment in the short run. They will have a effect on prices also. There seems to e a trade-off between inflation and unemployment.

Another important result of the present study is regarding negative and statistically significant estimate of β_3 in equation (8). It represents a combined effect of two parameters, h and q from equation (5) and (6). Parameters h represents the sensitivity of the rate of inflation to the rate of recovery(growth) in the economy, where as q is the Okun's parameter reflecting the cost of unemployment in excess the natural rate of unemployment. Since the Okun's coefficient q depends on the overall marginal productivity of labour in the whole economy, we can reasonably assume that it would be positive for any economy developed or underdeveloped. Thus, the negative estimate for the coefficient β_3 implies that h is negative for the Indian economy. The strategy of rapid recovery or fast growth to reduce involuntary unemployment in the Indian economy is not likely to fuel inflationary prices. On the contrary, however, the strategy of slow recovery in likely to aggravate inflationary pressures I the Indian economy.

The well known argument that the Indian labour force in characterized by the phenomenon of disguise and under employment like most other developing countries and that a rapid rise in demand for labour, therefore, does not raise wages does not seem to hold good according to the present results. This, may be because of two reasons : First Indian is a democratic country and people or labour does hesitate. Despite presence of under employment and disguised unemployment, when the demand for a particular skilled labour increases, the pressure on wages increases as there are complementary among differently skilled labour.

4.3 Granger Causality Tests

Granger (1969) developed a simple procedure for testing causality. According to this test a variable x_t is said to Granger-Cause y_t, if y_t can be predicted with greater accuracy by using past values of the x_t variable rather than not using such past values, all other terms remaining same.

The Granger-causality test for the case of one equation and two variables proceeds as follows:

First, $y_t$is regressed on lagged y terms as

$$y_t=\alpha_1+\sum_{j=1}^{m}\gamma_j y_{t-j}+ u_{1t} \qquad \text{….(1)}$$

and find restricted residual sum of squares, RSS_R

Again y_t is regressed on lagged y terms plus lagged x terms as :

$$y_t=\alpha_1+\sum_{i=1}^{n}\beta_i x_{t-i}+ \sum_{j=1}^{m}\gamma_j y_{t-j} + u_{2t} \qquad \text{….(2)}$$

and obtained unrestricted residual sum of squares, RSS_U, then, $((RSS_R - RSS_U)/m) / (RSS_U/n-k)$ follows the Fm, n-k distribution, k=m+n+1.

The null hypothesis that x_t does not cause y_t ($\sum_{i=1}^{n} \beta_i=0$) is rejected if the computed value of F-statistic exceeds the tabulated value at a specified level of significance.

The causality tests performed by application of E-views software are summarized in the following table (4.3).

Table: 4.6

Granger Causality Tests

Null Hypothesis	observations	F-statistic	Probability
((y – y*)/y*)does not Granger CauseInfl(GNPD)	55	3.722	0.031
Infl(GNPD) does not Granger Cause((y – y*)/y*)	55	1.376	0.262
(Gy – Gy*) does not Granger CauseInfl(GNPD)	55	2.915	0.064
Infl(GNPD) does not Granger Cause (Gy – Gy*)	55	6.923	0.002

The first row of above table shows that the null hypothesis, ((y – y*) / y*) does not Granger Cause Infl(GNPD), is rejected at 3.1 percent level of significance and therefore, output gap ratio ((y – y*) / y*) Granger causes Infl(GNPD). The null hypothesis, Infl(GNPD) does not Granger Cause ((y – y*) / y*), can't be rejected due to non-significance result as is evident from second row of the table. So, there is a unidirectional causal relationship between Output gap ration ((y – y*) / y*) and GNP Deflator based inflation rate. In other words the output gap ratio Granger causes the inflation and not vice versa.

The third row shows that the null hypothesis,(Gy – Gy*) does not Granger Cause Infl(GNPD), is rejected at 6.4 percent level of significance and therefore, (Gy– Gy*) Granger Causes Infl(GNPD). Similarly, it can be seen that the null hypothesis, Infl(GNPD) does not Granger Cause (Gy – Gy*), is rejected at 0.2 percent level of significance and a change in GNP Deflator based inflation effects the gap of output growth rate (Gy – Gy*). Hence, there is a bidirectional causal relationship between gap of output growth rate and GNP Deflator based inflation rate.

In other words, the gap of output growth rates Granger causes the GNP based inflation rate and GNP based inflation rate Granger causes gap of output growth rate i.e. there is a feedback or bidirectional causality relationship.