Co-Integration Analysis Of The Determinants Of Inflation In India

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ABSTRACT

Inflation refers to a general rise in prices measured against a standard level of purchasing power. The most well-known measures of Inflation are the CPI, which measures consumer prices, and the GDP deflator, which measures inflation in the whole domestic economy. In India, the average inflation rate from 1969 to 2010 is measured at 7.99 percent with historical high of 34.68 percent (September 1974) and a record low of -11.31 percent (May 1976). Economists generally agree that high rates of inflation are caused by an excessive growth of money supply, but there are many factors (real or monetary) which have an influence on inflation indices. This paper seeks to shed some light on the determinants of inflation in India during April 2001-March 2011, and to estimate a more specific relationship between inflation and its determinants using Johansen Co-integration and Vector Error Correction Model (VECM). The Johansen Co-integration test applied on selected data indicated four long run equilibrium relationships for inflation with its determinants. The results of VECM indicated a positive relationship between GDP and the CPI, and a high degree of interdependence between money supply, crude oil prices and inflation in India.

Keywords: Inflation, Vector Error Correction, Co-integration
JEL Classification Codes: B22, C32, E31, E50, E60

INTRODUCTION

Inflation is rise in the general level of prices of goods and services in an economy in a given period of time. When the general price level rises, each unit of currency buys fewer goods and services. Thus, inflation also reflects erosion in the purchasing power of money – a loss of real value in the internal medium of exchange and unit of account in the economy. On the one hand, effects of inflation on an economy are positive as they ensure central banks adjust rates and encourage investment in non-monetary capital projects, on the other; the effects may be negative as they include a decrease in the real value of money and other monetary items overtime. Uncertainty over future inflation may discourage investment and savings, and high inflation may lead to shortage of goods if consumers begin hoarding out of concern that prices will increase in the future.

The inflation rate in India was recorded to be the highest in September 1974 (34.68 percent) and lowest in May 1976 (-11.31 percent) during the last three decades (average inflation rate during this period was 7.99 percent). The last recorded inflation rate in India was 8.43 percent in July 2011. Economists generally agree that the high rates of inflation are caused by an excessive growth of supply ; low or moderate inflation may be attributed to fluctuations in real demand for goods and services as well as the growth in the money supply. However, long sustained period of inflation is caused by money supply growing at a faster rate than the rate of economic growth. Dlamini et al. (2001) revealed that inflation rate in the economy is significantly related to the other macroeconomic determinants of the country. Important among them are Gross Domestic Product (GDP) and Index of Industrial Production (IIP). Increase in nominal wage rates is another factor expected to have contributed positively to the rise in the price level in India. Further, the relationship between the inflation rate and the nominal prime-lending rate is supposed to be positive on the basis of theoretical expectation. Changes in the international prices (such as oil prices) and changes in the exchange rates also have an impact on inflation in the domestic market.

There are various measures of inflation which depend on specific circumstances. A chief measure of price inflation is the inflation rate, the annualized percentage change in a general price index over time, known as the Consumer Price Index (CPI). In this paper, the researchers focus on the CPI as the measure of inflation because changes in CPI are used to assess price changes associated with the cost of living. CPI is one of the most frequently used statistics for

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identifying state of inflation or deflation. The present paper seeks to investigate the possible relationship (both the long-run equilibrium and short-run dynamics) between monthly Consumer Price Index (CPI) and its selected macroeconomic determinants.

LITERATURE REVIEW

Numerous studies have been conducted on the inflationary process in both developing and developed countries. Following is a brief review of some of the studies to identify possible determinants of inflation in India.

Canetti & Greene (1991) used Granger and Pierce's causality tests for investigating the role of domestic money supply on inflation changes for six African countries, and found that growth in money supply, and the nominal exchange rate had a significant casual influence on inflation. Bank of Botswana (1998) in "Inflation in Southern Africa" considered changes in the cost of labour a major cause of inflation variations in developed countries, but not in developing countries. It further mentioned that in an open and import dependent economy, where domestic inflation is largely determined by foreign prices and nominal exchange rate depreciation, the initial improvement of export competitiveness resulting from depreciation may eventually be offset by the consequent increase in prices.

Altissimo et al. (2005) analyzed the long-run determinants of inflation differentials in a monetary union. The study aimed at establishing some stylized facts relating the regional dispersion in headline inflation rates in the Euro area as well as in the main components of Consumer Price Index. The researchers found that a relatively large proportion of inflation occured in the Service category of the EU's harmonized consumer price index. Andersson et al. (2009) also analyzed the determinants of inflation differentials and price levels in the Euro countries. Using dynamical panel analysis, the researchers concluded that inflation differentials are primarily determined by cyclical positions and the inflation persistence. Akbari & Rankaduwa (2005) in their paper titled “Determinants of Inflation and Feasibility of Inflation Targeting in a Small Emerging Market Economy: The Case of Pakistan” used econometric analysis to identify key determinants of inflation in Pakistan. The evidence presented in the study suggested that political stability and better functioning of markets are essential pre-requisites for achieving the desired effects of any macroeconomic policy.

Saryal (2007) applied the GARCH model to estimate conditional stock market volatility using monthly data series in Turkey and Canada and found that the rate of inflation has a high predictive power for stock market volatility in Turkey, whereas it is weaker, but still significant for Canada. The study suggested that higher rates of inflation are coincident with greater stock market risk. Kandil & Morsy (2009) studied the determinants of inflation in the Gulf Cooperation Council (GCC) since 2003. Using an empirical model that included domestic and external factors, the author found that inflation in major trading partners of GCC appears to be the most relevant to domestic inflation in GCC. Further, higher public investment in Kuwait, Oman, and the United Arab Emirates is found to have main inflationary pressure in the long run.

Bhattacharya & Mukherjee (2003) using the unit–root test, co-integration and the long-run Granger non-causality test investigated the nature of causal relationship between stock prices and macroeconomic aggregates in the foreign sector in India. They found no causal linkage between stock prices and the variables under consideration. Kishor (2009) studied the role of real money gap and the deviation of real money balance from its long-run equilibrium level for predicting inflation in India. He found the real money gap to be a significant predictor of inflation in India. The empirical results of the study conducted by Patra & Ray (2010) indicated that inflation expectations play a significant role in setting and conducting monetary policy in modern India. They also mentioned that imperfect information regarding the central bank's intentions has been one of the sources of inertia in the formation of inflation expectations.

Atanda and Odusanya (2010) critically analyzed the dynamic and simultaneous inter-relationship between inflation and its determinants in Nigeria between 1970 and 2007. They used Augmented Dickey Fuller test for checking time series properties of variables under consideration. For examining long-run and short-run mechanism of interaction between inflation and its determinants, they used Augmented Engle-Granger co-integration test and Error Correction Mechanism model respectively. Jaradat et al. (2011) used the concept of co-integration, Error Correction Model and Impulse Response Function to identify the most important internal and external factors of inflation, and to measure the impact of these factors on inflation dynamics in Jordan. Bashir et al. (2011) examined the demand side and supply side determinants of inflation in Pakistan on economic and econometric criterion. They investigated long run and short-run estimates using Johansen co-integration and Vector Error Correction approach and also examined the causal

relationship between some macroeconomic variables by using Granger's causality test.
Keeping in mind the methodology and the results of various research works carried out on the issue, the present paper attempts to analyze the co-integrative relationship between inflation in India and its principal macroeconomic determinants. The study is an addition to the existing knowledge on the subject. The findings of the study would be beneficial to multiple groups of people, e.g., policy makers, corporates, financial institutions, and the investors. It is further hoped that the study would open new vistas of research for academicians, researchers and students working in the area of macroeconomics in general and inflation in particular.

DATA AND METHODOLOGY

❖ **Data Description:** The analysis includes Gross Domestic Product, Money supply, Prime lending rate, Nominal exchange rate, Index of wages, Index of Industrial Production and International crude oil prices as explanatory variables; and Consumer price indices as explained variable. For analysis purpose, monthly observations of all the data sets spanning from April 2001 to March 2011 (ten financial years) were taken into consideration. The detailed description of variables under consideration is presented in the Table 1.

Table 1: List of Variables

Variable Name	Symbol	Data Source	Frequency (No. of Obs.)
Explained Variable			
Consumer Price Index Monthly Average (Base : 2000-01)	CPI	www.rbi.org	Monthly (120)
Explanatory Variables			
Gross Domestic Product (Thousand Crore ₹)	GDP	www.rbi.org	Monthly (120)
Index of Industrial Production (Base : 1993-94)	IIP	www.rbi.org	Monthly (120)
Money Supply: M3 (Thousand Crore ₹)	MOS	www.rbi.org	Monthly (120)
Interest Rate (Prime Lending Rate)	PLR	www.rbi.org	Monthly (120)
Index of Wage Rate (Base: 1963-65)	IWR	labour.nic.in	Monthly (120)
Foreign Exchange Rate (₹ per unit of US $)	EXR	www.rbi.org	Monthly (120)
Crude Oil Spot Price (WTI Dollars per Barrel)	CRO	www.eia.org	Monthly (120)
Source: Authors' Research			

RESEARCH METHODOLOGY

The following econometric tools (available in STATA IC 10 software) were applied for empirical investigation.

❖ **Unit Root Test:** Before using the time-series data for further investigation, it must be tested for unit root and stationarity. To test the stationarity, Augmented Dickey Fuller (ADF) test for unit root, 't' test for checking the favor of stationarity were applied. The test is based on the null hypothesis that the variable contains a unit root, and alternative hypothesis is that the variables are generated by a stationary process. The model form of the ADF test is as follows :

$$\Delta y_t = \alpha + \beta y_{t-1} + \delta t + \zeta_1 \Delta y_{t-1} + \zeta_2 \Delta y_{t-2} + \cdots + \zeta_k \Delta y_{t-k} + \varepsilon_t$$

Where, k is the number of lags, y_t is the time series data under consideration, and t is a time. The null hypothesis of the existence of a unit root is H_o; $\delta = 0$. In the model, ε_t denotes the error term.

❖ **Johansen Co-integration:** In econometrics, before estimating the parameters of VECM, an investigator has to choose the number of co-integrating equations. Co-integration means the long-run equilibrium relationship among the variables, which interprets that if the time-series data are co-integrated, then those series in the long run will come to an equilibrium point. The present study employs Johansen's method to estimate the co-integrating rank of a VECM. Johansen proposed two different likelihood ratio tests of significance, named Trace Statistic Test and Maximum Eigen Value Test. The researchers in this paper have applied both the tests to identify a proper number of co-integrating equations. Johansen's model for Trace Statistic is expressed as :

$$Qtrace = -T \sum_{i-r+1}^{k} \ln(1-\lambda_i)$$

Where, T is the number of observations and λi is the largest ith eigenvalue. This tests the null hypothesis of r co-integrating vectors against the null hypothesis of k co-integrating vectors. The alternative hypothesis of this method is that the number of co-integrating equations is strictly larger than the number of r under the null hypothesis. Instead, one could assume a given r under the null hypothesis and test this against the alternative that there are r+1 co-integrating equations. Johansen derived a likelihood-ratio test of the null r co-integrating relations against the alternative of r+1 co-integrating relations. As the part of the log likelihood that changes with r is a simple function of the eigenvalues of (K x K) matrix, this test is known as the maximum-eigenvalue statistic. This method is less used than the trace statistic as there is no evidence of getting a solution to the multiple - testing problems using a maximum-eigenvalue statistic. It is important to mention here that these tests are limited to tell the number of co-integrating equations only, not the co-integrating variables.

❖ **Vector Error Correction Model:** VECMs are used to model the stationary relationships between multiple time series that contain unit roots. VECM implements Johansen's approach for estimating parameters. If x_t and y_t are co-integrated, there is a long-run equilibrium relationship between them. Further, short-run dynamics can also be described by the error correction model. This is known as Granger's representation theorem.

If $x_t \sim I(1)$, $y_t \sim I(1)$, and $z_t = y_t - \beta x_t$ is I (0), then x and yare said to be co-integrated. The Granger representation theorem says that in this case, x_t and y_t may be considered to be generated by VECMs as:

$$\Delta x_t = \rho_1 z_{t-1} + \text{lagged}(\Delta x_t, \Delta y_t) + \varepsilon_{1t}$$

$$\Delta x_t = \rho_2 z_{t-1} + \text{lagged}(\Delta x_t, \Delta y_t) + \varepsilon_{2t}$$

Where, at least one of ρ_1 and ρ_2 is non-zero and ε_{1t} and ε_{2t} are the white noise errors.

ANALYSIS AND EMPIRICAL RESULTS

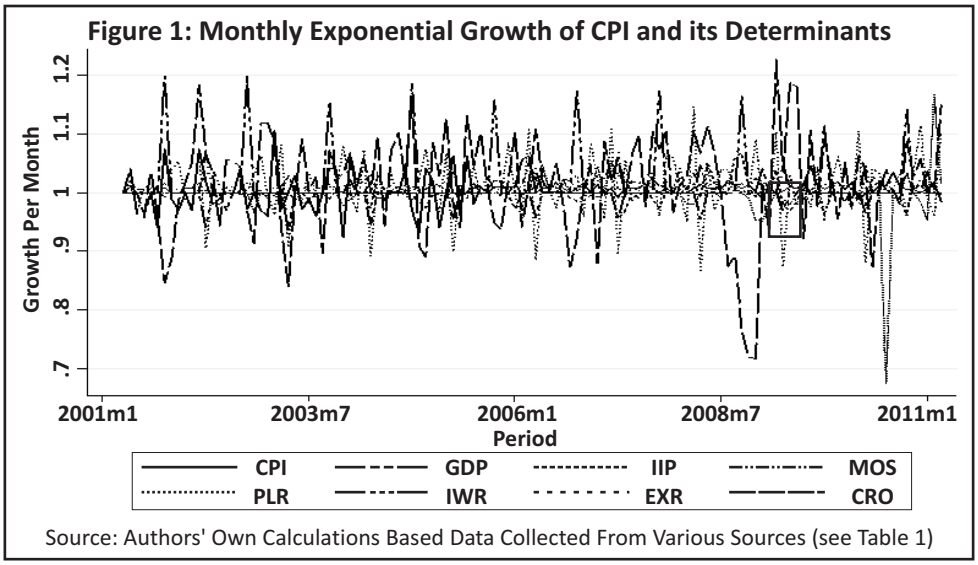
❖ **Summary Statistics:** The relevant information about the selected explained and explanatory variables is summarized in the Table 2. The number of observations for all the variables is one hundred twenty as the study covers monthly observations for ten years.

Table 2: Results of Summary Statistics

Var.	Obs.	Min.	Max.	Mean	S.D.	Variance	Skewness (SE)	Kurtosis (SE)
CPI	120	95.00	188.00	124.79	27.84	775.15	0.788 (.221)	-0.627 (.438)
GDP	120	433.00	1535.00	838.83	307.34	94460.00	0.581 (.221)	-0.794 (.438)
IIP	120	154.90	350.40	221.59	49.38	2439.00	0.440 (.221)	-0.871 (.438)
MOS	120	1348.00	6496.00	3159.10	1505.51	2267000.00	0.644 (.221)	-0.867 (.438)
PLR	120	7.50	13.62	11.22	1.23	1.53	-0.858 (.221)	1.829 (.438)
IWR	120	3438.70	5112.40	4198.00	529.46	280300.00	0.343 (.221)	-1.147 (.438)
EXR	120	39.32	51.20	45.55	2.55	6.53	-0.661 (.221)	0.179 (.438)
CRO	120	19.38	133.88	57.66	26.36	695.10	0.615 (.221)	0.007 (.438)

Source: Authors' Research

Results of descriptive statistics show that over the period from 2001-02 to 2010-11, CPI fluctuated between 95 and 188 points. The relative range for the values of other variables is highest in case of CRO and lowest for EXR. The values of mean and standard deviation shown in the table indicate clearly that relatively EXR and PLR are the most consistent variables, but MOS, IWR, CRO, and GDP are the most inconsistent variables as they have maximum coefficient of variation. The Table 2 also shows positive skewness for all the distributions except PLR and EXR. It indicates that the large tail of the distribution lies towards the higher values of the variable. Kurtosis, the degree of peakedness in a curve of the frequency distribution is highest for PLR and lowest for CRO. For tracing the closeness



Source: Authors' Own Calculations Based Data Collected From Various Sources (see Table 1)

Table 3: VEC Lag Order Selection Criterion

Lag	LR	FPE	AIC	SIC	HQIC
0	---	6.2e+19	68.2814	68.3585	68.4713
1	2084.60	3.0e+12	51.4137	52.1075	53.1228*
2	204.30	1.5e+12	50.7548	52.0654	53.9832
3	199.98	8.7e+11	50.1343	52.0616*	54.8819
4	185.03	5.7e+11*	49.6427*	52.1867	55.9095

Notes: * Indicates lag order selected by the criterion

Source: Authors' Research

between the volatility in CPI and its determinants, monthly exponential growth of all the variables is depicted in the Figure 1.

❖ **Lag Order Selection:** To identify proper lag order for conducting co-integration analysis and vector error correction modeling, the researchers applied several minimum value based criterions. The results of Likelihood Ratio (LR) test are presented in the Table 3. Based on the results of the LR test, a model with four lags order was selected. The Final Prediction Error (FPE) and Akaike Information Criterion (AIC) also suggested lags order of four for the model. However, Schwarz Information Criterion (SIC) and Hannan-Quinn Information Criterion (HQIC) chose a model

Table 4: Results of The Augmented Dickey Fuller Test

Variables	Z(t)	P-Value
CPI	2.184	0.998
GDP	0.690	0.989
IIP	0.618	0.988
MOS	4.909	1.000
PLR	-1.537	0.515
IWR	0.095	0.965
EXR	-2.317	0.166
CRO	-1.533	0.517

Note: 1%, 5 % and 10% critical values are -3.505, -2.889 and -2.579 respectively.

Source: Authors' Research

with three lags and one lag respectively.

❖ **Augmented Dickey Fuller Unit Root Test:** Before applying co-integration analysis on the selected variables, a formal test is required to confirm time series properties. For this purpose, the Augmented Dickey Fuller (ADF) test of unit root is applied. The lag length is four based on the FPE and AIC. In this test, the null hypothesis is a variable that contains a unit root, and alternative hypothesis is that the variables are generated by a stationary process. The results of the ADF test are presented in the Table 4. The test results indicate that the t value of almost all the variables is less than the critical value. Hence, the null hypothesis is accepted, and it can be said that these variables are generated by a non-stationary process.

❖ **Johansen Co-integration Test:** Johansen Co-integration test is applied to investigate the long-run relationship between the variables under study if the data set is non-stationary. In case the variables are generated by a stationary process, we apply vector auto-regression. Since the variables under study are generated by a non-stationary process, the researchers applied the Johansen Co-integration test with a view to find out the long-run relationship between CPI and the selected explanatory variables. The empirical results of Johansen Co-integration test are presented in the Table 5.

Here, the null hypothesis is that there is no co-integrating equation among the selected variables. However, the results of Johansen Co-integration test show the value of trace statistic to be 39.407, which is less than the critical value 47.21

Table 5: Results of Johansen Co-integration Test (Trace Statistics)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5% Critical Value
None	---	269.295	156.00
At most 1	0.596	164.096	124.24
At most 2	0.378	108.873	94.15
At most 3	0.283	70.245	68.52
At most 4	0.233	**39.407***	**47.21**
At most 5	0.151	20.373	29.68
At most 6	0.104	7.630	15.41
At most 7	0.045	2.229	3.76
At most 8	0.019	---	---

Note: * Denotes acceptance of null hypothesis at 5% level of significance.

Source: Authors' Research

Table 6: Results of Johansen Co-integration Test (Maximum Eigenvalue Statistics)

Hypothesized No. of CE(s)	Eigenvalue	Max Statistic	5% Critical Value
None	---	105.19	51.42
At most 1	0.596	85.22	45.28
At most 2	0.378	66.62	39.37
At most 3	0.283	37.83	33.46
At most 4	0.233	**19.03***	**27.07**
At most 5	0.151	12.74	20.97
At most 6	0.104	5.40	14.07
At most 7	0.045	2.22	3.76
At most 8	0.019	---	---

Note: *Denotes acceptance of null hypothesis at 5% level of significance.

Source: Authors' Research

for at the most four co-integrating equations at 5% level of significance. Hence, it can be concluded that there were four co-integrating equations among the selected variables. To identify a proper number of co-integrating equations, the researchers also applied Maximum Eigenvalue Statistic test on CPI and the selected explanatory variables. The test results are presented in the Table 6.

The results contained in the Table 6 shows clearly that the value of the maximum eigenvalue statistic is 19.03, which is less than the critical value 27.07 at 5% level of significance for at most four co-integrating equations. Since, we have chosen the values at 5% level of significance for Vector Error Correction Model (VECM), there are four long-run equilibrium relationships between CPI and its selected determinants.

❖ **Vector Error Correction Model (VECM):** To investigate short run dynamics between inflation and its determinants, the researchers made an attempt to apply Vector Error Correction Model (VECM). The results of multivariate VECM with four lags and four co-integrating equations are presented in the Table 7. The table contains values of adjustment coefficient (short run parameters) of the model developed for Consumer Price Index (CPI) and its determinants. It shows highest adjustment coefficients of Gross Domestic Product (GDP: 3.662) for CPI at its second lag difference. It indicates that CPI adjusts quickly towards changes in monthly growth rate in GDP. After GDP, the CPI follows the changes in Index of Wage Rate (IWR) and Money Supply (MOS). Their coefficients are 1.948 and 0.758 respectively at their second lag difference. Further, the CPI also adjusts itself towards the fluctuations in industrial production (adjustment coefficient of IIP being 0.163 at second lag difference), followed by variations in Crude Oil Spot Prices (CRO) and Foreign Exchange Rate (EXR) as their adjustment coefficients are 0.131and 0.018 at second and first difference. But, the effect of these variables on CPI is not strong as they have low degree coefficients. Role of Interest

Table 7: Vector Error Correction Model in a Multivariate Framework

	CPI_{LD}	CPI_{L2D}	CPI_{L3D}	GDP_{LD}	GDP_{L2D}	GDP_{L3D}
D_CPI				0.000	-0.009	-0.012
D_GDP	3.239	3.662	1.883			
	CPI_{LD}	CPI_{L2D}	CPI_{L3D}	IIP_{LD}	IIP_{L2D}	IIP_{L3D}
D_CPI				-0.084	-0.101	-0.012
D_IIP	0.139	0.163	-0.136			
	CPI_{LD}	CPI_{L2D}	CPI_{L3D}	MOS_{LD}	MOS_{L2D}	MOS_{L3D}
D_CPI				-0.018	-0.018	-0.012
D_MOS	0.536	0.758	0.693			
	CPI_{LD}	CPI_{L2D}	CPI_{L3D}	PLR_{LD}	PLR_{L2D}	PLR_{L3D}
D_CPI				-2.087	-0.303	0.219
D_PLR	0.000	0.011	0.010			
	CPI_{LD}	CPI_{L2D}	CPI_{L3D}	IWR_{LD}	IWR_{L2D}	IWR_{L3D}
D_CPI				0.005	-0.009	-0.003
D_IWR	0.717	1.948	-0.151			
	CPI_{LD}	CPI_{L2D}	CPI_{L3D}	EXR_{LD}	EXR_{L2D}	EXR_{L3D}
D_CPI				-0.630	0.075	-0.625
D_EXR	0.018	0.005	-0.016			
	CPI_{LD}	CPI_{L2D}	CPI_{L3D}	CRO_{LD}	CRO_{L2D}	CRO_{L3D}
D_CPI				-0.092	0.014	0.088
D_CRO	0.119	0.131	0.036			

Notes: LD, L2D and L3D refer the value of adjustment coefficient for first lag difference, second lag difference and third lag difference respectively.

Source: Authors' Research

Rates (PLR) is the lowest (adjustment coefficient being 0.011 at the second lag difference) in the short run dynamics of CPI. Thus, CPI follows the changes in domestic macroeconomic indicators before changes in the international indicators. All this description is about short run adjustments of CPI for its determinants. The results of short run adjustment of the determinants of CPI towards it are adverse as PLR is found to be adjusting itself quickly with the changes in CPI level. Among other selected variables, GDP is the second last and IWR is the last follower of change in CPI.

CONCLUSION

In a modest endeavour to investigate the long run equilibrium and short run dynamic relationship between inflation and its determinants in India using Johansen co-integration test, the results indicate four long run equilibrium relationships for inflation with its determinants. Comparing inflation rate against the growth rate of GDP, one would expect an adverse relationship, but the results of VECM indicated a positive relationship between GDP and the CPI. Economic theory suggests a high degree of interdependence between money supply and inflation, and it is supported by the present study too. Changes in international prices of crude oil also are found to have a notable impact on inflation in India. The evidences of analysis support the conclusions drawn in previous studies too conducted on inflationary process by Dlamini et al. (2001), Kandil and Morsy (2009), Kishor (2009), and Patra and Ray (2010).

LIMITATIONS OF THE STUDY

Inflation has been extensively a topic of research in many developed nations, especially in the US and UK. However, not much work has been done in this area in India. The present paper is an attempt to analyze co-integrative relationship between inflation in India and its principal macroeconomic determinants. As the study is based on secondary information only, it carries all the limitations inherent with the use of secondary data. The study could not incorporate the views and opinions of the business communities and civil society in the sphere of inflation-related issues. Further, the study is based on macroeconomic determinants only. It does not consider microeconomic determinants that may affect inflation.

SCOPE FOR FUTURE RESEARCH

Someone very rightly mentioned "No work is complete till you stop trying". The researchers felt that there is scope for further research, improvements and additional insight. Over time, as the database expands, further studies may use other variables or study some more micro and macro aspects related to the problem.

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