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Is CPI generated from stationary process? An investigation on unit root hypothesis of India's CPI

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Abstract: In this paper, the Consumer Price Index (CPI) of India is tested on whether it is generated from a stationary process for the purpose of which, a set of time series data on CPI with 4,420 observation arranged on daily basis from November 10, 2003 to December 16, 2015 is retrieved from the official website of National Bureau of Economic Research. The testing procedure includes fitted OLS regression on which the Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) unit root test are computed. The statistical analysis of both ADF and PP exhibit a smaller test statistic value for CPI than the critical value at 0.05 which means that CPI is not generated from a stationary process and it follows unit root at level, though, it does not follow unit root and it is stationary at its first difference. Therefore, we reject the null hypothesis in favor of the alternative.

Keyword: **CPI; Unit Root; Stationary Process; Augmented Dickey Fuller; Philips-Perron**

1. INTRODUCTION

1.1 Background and Purpose

The Consumer Price Index (CPI) is the base of measurement for changes in the retail prices of economic commodities that are exchanged between the suppliers and the households over time on which other economic variables like inflation, cost of living, cost of substitution are also measured (see for instance, [1]; [2]; [3]). A series of studies demonstrate that consumers are inclined to believe that the selling price of goods or services is substantially higher than its fair price [4] which shows an upward trend in CPI and consumer's sensitivity with regards to this economic phenomenon [5]. The accurate measurement of the past fluctuation and forward forecasting of CPI calls for a theoretical foundation of this phenomenon both for statistical agencies and for a complex business process. [6] states that there are several issues that need theoretical argument such as; what is an appropriate theoretical consumer price index to measure; what are some of the possible sources of biases between the fixed base Laspeyres price index and the theoretical cost-of-living index; and what factors will make the biases larger or smaller and how will the biases change as the general inflation rate changes. In a real economy, there are many factors that affect CPI to increase over time [7] and one of the significant contributor which causes the CPI to increase or decrease is the degree of import to a country [8] though, other studies exhibit exchange rate as a significant factor that effects CPI both in short run and long run [9]; [10]. According to [11] Consumer Price Index (CPI) is generally used for three possible purposes like 1) as a Cost of Living Index i.e., as a measure of the relative cost of achieving the standard of living when facing two different sets of prices for the same group of commodities; 2) as a consumption deflator i.e., the price change component for a decomposition of a value ratio into price and quantity components and; 3) as a measure of general inflation.

Drawing on the work of [12], in this paper we attempt to investigate the base of CPI fluctuation with the view of its stationarity and unit root for the sake of which, we examine a set of time series data with total 4,420 daily observation of India's CPI. The rest of the paper is organized as follow: section 2 discusses about data and the econometric models applied in this paper, section 3 presents the findings and results followed by section 4 which concludes the paper.

1.2 Statement of Research Question

An upward slop of the Consumer Price Index is a matter of concern for the household in general and for the economic policymakers in particular. In this paper, a question raises on whether the CPI is stationary and whether it follows unit root?

1.3 Research Hypothesis

This paper aims to examine whether the CPI is generated from a stationary process for which, the following hypothesis is formulated:

H_0: The CPI is generated from a stationary process and does not follow unit root.
H_A: The CPI is not generated from a stationary process and follows unit root.

1.4 Research Objectives

This research is designed to achieve the following identical objectives:

- To determine whether the CPI is generated from a stationary process and;

- To document the path of CPI trend and its impulsiveness throughout the concerned period.

1.5 Research Limitation

This paper is about the identical economic variable of India throughout a specific time period and the results found through an empirical investigation in this paper, cannot be generalized.

2. DATA AND MODEL

2.1 Data

A set of time series data which represents the daily CPI (Consumer Price Index) of India is used in this paper which includes 4,420 observation for the period November 10, 2003 to December 16, 2015. The data is retrieved from the official website of National Bureau of Economic Research (NBER) using the Quadl spreadsheet method.

2.2 The Model

To obtain an accurate result and to approach a rational finding and conclusion, the following econometric testing models are used that a brief discussion of which is provided below in sequential order.

2.2.1 OLS Regression

We apply a Gaussian error Ordinary Least Square (OLS) regression of an AR(1) process as an initial estimation of the variable on a constant form. The OLS function fits with our dataset can be written as:

$$y_t = py_{t-1} + \varepsilon_t \tag{1}$$

where ε_t is independent and specifically distributed as $N(0,\sigma^2)$ and OLS regression is based on the number of observation in time series data of the serial correlation given by p as:

$$\hat{\rho}_n = \frac{\sum_{t=1}^{n} y_t - 1y_t}{\sum_{t=1}^{n} y_t^2} \tag{2}$$

where if $|\rho| < 1$ then $\sqrt{n}\left(\hat{\rho}_n - \rho\right) \rightarrow N\left(0,1-\hat{\rho}^2\right)$ and by getting a valid result, then the result would have a variance = 0.

2.2.2 Augmented Dickey Fuller Test

The basic argument is that the variable does not follows unit root and it is stationary for the purpose of which, we apply the ADF model developed by Dickey & Fuller [13] to test the null hypothesis being the variable is generated from a stationary process against the alternative. The ADF model equation we fit can be written as:

$$\Delta y_t = \alpha + \beta y_{t-1} + \delta_t + \sum_{j=1}^{k} \varsigma_j \Delta y_{t-j} + e_t \tag{3}$$

Where k is the number of lags and on the OLS estimation the test statistics for $H_O : \beta = 0$ is $Z_t = \hat{\beta} / \hat{\sigma}_\beta$ and $\hat{\sigma}_\beta$ is the standard error of $\hat{\beta}$ while the critical values that are included in the output are linearly interpolated from the table of values that appear in [14]), and the MacKinnon approximate p-values use the regression surface published in [15], [16].

2.2.3 Philips-Perron Unit Root Test

The final model we apply to test the null hypothesis that CPI contains unit root and is nonstationary is the Philips-Perron [17] Unit root test. The model uses the Newey-West [18] standard error to control for the autocorrelation in the series. The PP equation we fit on estimated OLS regression is expressed as:

$$Z_p = n\left(\hat{\rho}_n - 1\right) - \frac{1}{2}\frac{n^2 - \hat{\sigma}^2}{S_n^2}\left(\hat{\lambda}_n^2 - \hat{\gamma}_{0,n}\right)$$

$$Z_t = \sqrt{\frac{\hat{\gamma}_{o,n}}{\hat{\lambda}_n^2}}\frac{\hat{\rho}_n - 1}{\hat{\sigma}} - \frac{1}{2}\left(\hat{\lambda}_n^2 - \hat{\gamma}_{o,n}\right)\frac{1}{\lambda_n}\frac{n\hat{\sigma}}{S_n}$$

$$\hat{\gamma}_{o,n} = \frac{1}{n}\sum_{i=j+1}^{n} \hat{u}_i \hat{u}_{i-j} \tag{4}$$

$$\hat{\lambda}_n^2 = \hat{\gamma}_{o,n} + 2\sum_{j=1}^{q}\left(1 - \frac{j}{q-1}\right)\hat{\gamma}_{j,n}$$

$$S_n^2 = \frac{1}{n-k}\sum_{i=1}^{n} \hat{u}_i^2$$

Where u_t is the OLS (Ordinary Leas Squared) residual, k is the number of covariates in the regression, q is the number of Newey-West lags to use in calculating the $\hat{\lambda}_n^2$ and $\hat{\sigma}$ is the OLS standard error of $\hat{\rho}$ [12].

3. RESULTS

In this section, we present the statistical analysis of the sample data which represents the Consumer Price Index of India from November 10, 2003 to December 16, 2015 arranged by daily basis with 4,420 observation in total (see, table 1 for descriptive statistics).

TABLE 1: Descriptive Statistics

Variable	Observation	Mean	Std. Dev.	Min.	Max.
CPI	4,420	18.26157	8.41665	5.44	33.3

Table 1 presents the descriptive statistics of the data that has been used in this study. The data presents daily CPI (Consumer Price Index) of India for the stated period. The competing hypothesis of the study is that the CPI follows unit root both at level. To begin with testing the data, a graphical presentation is used to provide an initial view of the data.

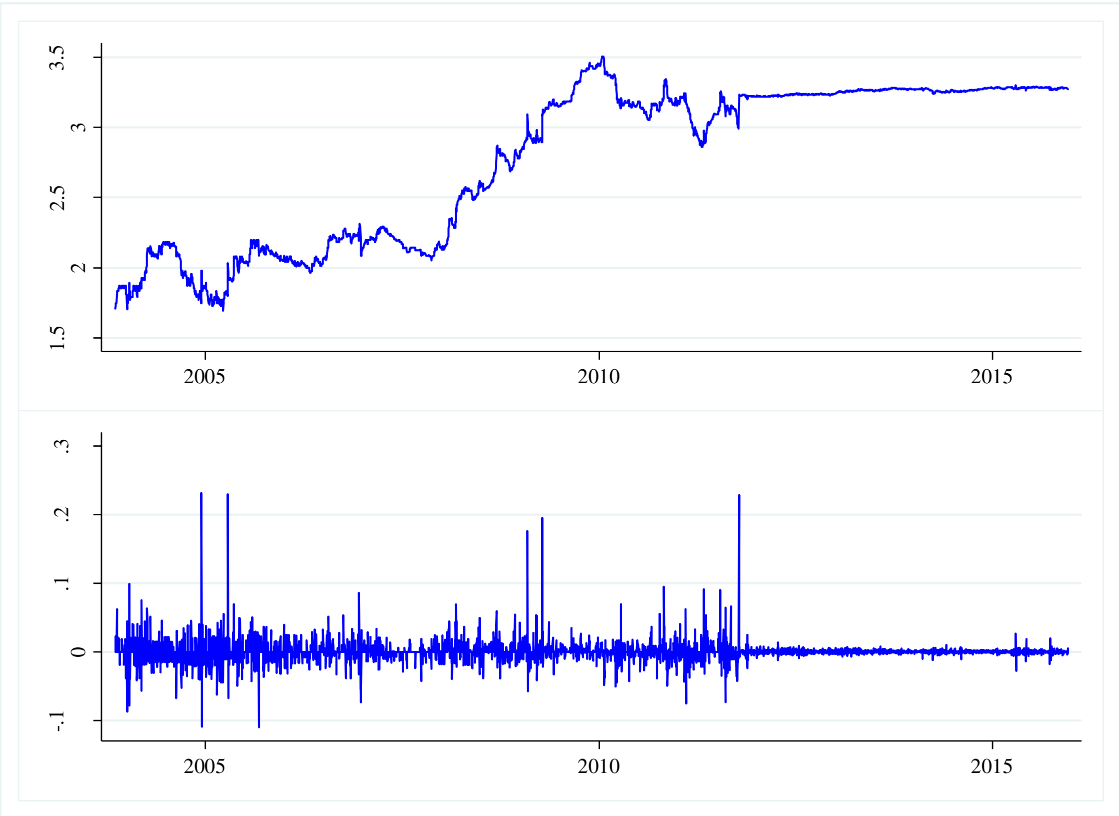

Fig. 1: CPI at level and at first difference

Fig. 1 shows a strong trend of the variable at level and seems to be non-stationary from which we can draw an initial opinion that CPI follows unit root at level. On the other hand, the variable at first difference shows no strong trend and presents stationarity (see also, [19]) which means that it does not follow unit root.

TABLE 2: OLS Regression

Source	SS	df	MS	R^2	Adjusted R^2
Model	0	0	.	0.000***	0.000***
Residual	1371.14938	4,419	.310284991		
Ln_CPI	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]
Constant	2.767422	.0083786	330.30	0.000***	2.750995 2.783848

***<0.01, **<0.05, *<0.10
Sample: 4,420

We first regress the variable at its natural logarithm on constant term and OLS form. The corresponding probability value of the test statistics shows 0.000 which is significant to explain the variable (CPI). The assumption is to compare the statistic p-value of the OLS with those of the ADF and PP (see, TABLE 3, 4 and 5) since both of the tests are based on the OLS regression model (see, [20]).

TABLE 3: ADF Test at level

	ADF regression with noconstant				ADF regression with time trend			
	Test Statistics	5% Critical Value	Coef.	P>|t|	Test Statistics	5% Critical Value	Coef.	P>|t|
Z(t)	1.346	-1.950	.0000992	0.178	-1.691	-3.410	4.01e-07	0.285
					MacKinnon approximate p-value for Z(t) = 0.7548			

Significant if t > c for nonstationarity
Significant if t < c for stationarity
Sample: 4,420

The Augmented Dickey Fuller (ADF) test in the above table presents statistical result with noconstant and time trend regressions. The noconstant test statistics value of 1.346 < 1.950 critical value at 5% which shows the nonstationarity of the variable at level. In addition, the regression with time trend exhibits a corresponding p-value of 1.691 for test statistics being < 3.410 critical value at 5% and this means that the variable with time trend is nonstationary and follows unit root (see, [21]; [22]; [23]).

TABLE 4: ADF Test at first difference

	ADF regression with noconstant				ADF regression with time trend			
	Test Statistics	5% Critical Value	Coef.	P>|t|	Test Statistics	5% Critical Value	Coef.	P>|t|
Z(t)	-71.338	-1.950	-1.070426	0.000***	-71.389	-3.410	-1.071381	0.000***
					MacKinnon approximate p-value for Z(t) = 0.000***			

Significant if t > c for nonstationarity
Significant if t < c for stationarity
***<0.01, **<0.05, *<0.10
Sample: 4,420

Table 4 presents the ADF test of the CPI at first difference with noconstant and time trend form. The variable's test statistics being 71.338 > 1.950 with a probability value of 0.000 shows the stationarity of the CPI and exhibits that it does not follow unit root. The first difference with time trend also presents t statistics value of 71.389 > 3.410 the critical value at 5% with a significant corresponding p-value of 0.000 which means that CPI is stationary and therefore, it does not follow unit root at its first difference (see, [24]; [25]).

TABLE 5: Philips Perron Unit Root Test

CPI at level				CPI at first difference			
Newey-West lags	Z(rho)	Test Statistics	5% Critical Value	Newey-West lags	Z(rho)	Test Statistics	5% Critical Value
9	-5.341	-1.526	-21.800	9	-4637.616	-71.520	-21.800
MacKinnon approximate p-value for Z(t) = 0.8200				MacKinnon approximate p-value for Z(t) = 0.0000***			

Significant if z > c for nonstationarity
Significant if z < c for stationarity
***<0.01, **<0.05, *<0.10
Sample: 4,420

In addition to Augmented Dickey Fuller test, the Philips-Perron test at level and first difference of CPI is presented in table 5. Both z and t statistics values being 5.341 and 1.526 are less the 21.800 the critical value at 5% at level shows that the variable is nonstationary and follows unit root while both z and t statistics value of 4637.616 and 71.520 are more than 21.800 critical value at 5% and exhibit the stationarity of CPI at first difference and document that it does not follow unit root.

4. CONCLUSION

A drastically changing Consumer Price is a matter of concern for consumers and a topic of interest for researchers. This economic phenomenon is oftenly considered as the base of measurement for many economic variables like inflation, cost of living and cost of substitution in a country. In this paper, we examine the competing hypothesis that India's CPI is generated from a stationary process and does not follow unit root at level for which, a set of time series data has been collected from the NBER official website which represents daily observation of more than 4,200 for the period November 10, 2003 to December 16, 2015. The statistical analysis and research findings show that the variable is not generated from a stationary process at level both in constant and with time trend while it does follow unit root and stationarity when it is converted into first difference. Therefore, we can conclude that India's CPI is generated from a stationary process at first difference though, it follows unit root at level.

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