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Empirical analysis of Indian commodity market data in linear and nonlinear frameworks

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Abstract: Predicting commodity price dynamics is very important for speculators as well as investors. This paper analyzes the Indian commodity price as well as production data with a view to ascertain whether a linear or nonlinear approach is best suited to model their behaviour. Investigations are carried out to ascertain the stationarity of price and production data corresponding to four agricultural commodities, four metal commodities, and the Indian Gross Domestic Product (GDP). Standard and advanced unit root tests and variance ratio statistics are used in the analyses. Cointegration tests are carried out to ascertain whether the commodity production data are co-integrated with the Indian GDP. Further, parameters of the Lewis model, as formulated by Deaton and Laroque (2003) under the assumption of a linear commodity price process, are estimated using a full information maximum likelihood (FIML) technique to verify how this model fits the data in the Indian commodity market. Later, with the help of advanced unit root tests, it is shown that the commodity prices under study are better represented by a nonlinear process.

Keywords: Indian commodity market data, Stationarity, Standard unit root tests, Co-integration test, Nonlinear unit root tests, ESTAR framework

INTRODUCTION

Modelling and analyses of commodity market data, especially the commodity prices, are of utmost importance to under-developed and developing countries engaged in commodity market trade. This helps them frame efficient economic policies. Commodity prices are characterized by a high degree of volatility, making it difficult to predict their behavior accurately over a period of time. The commodity prices may experience a sharp rise or fall over a short period of time; this has a serious influence on both the macroeconomic and microeconomic policies of countries whose gross national product (GDP) depends heavily on the export of such commodities. Understanding the commodity price dynamics is crucial not only for Governments, but also for other major players like hedgers and speculators involved in the commodity market trade. Thus, the study of the stochastic processes influencing the behavior of commodity prices is very important in such a scenario[1].

Commodity market research is widely being pursued in the literature. There exist a number of models that try to explain the behavior of commodity prices. The list starts with the pioneering work of Gustafson [2] who studied the optimal storage rules to benefit from a very good harvest, followed by the competitive storage model envisaged by Muth[3], which integrates the notion of rational expectations. Following this, Samuelson [4] proved the optimality of competitive storage and showed that a first order non-linear Markov process may be used to explain the behavior of commodity prices. Kohn [5], Newbery and Stiglitz [6] and Williams and Wright [7] are a few other important contributions in this direction.

Deaton and Laroque [1] prove that there exist a rational expectations equilibrium in commodity prices, discuss its general implications on their behavior, and then present conditions under which commodity prices follow a renewal process. Assuming identically and independently distributed (i.i.d.) harvest shocks, some of the stylized facts of commodity price behavior can be established [1]. But using this approach, it was not possible to generate high amounts of autocorrelation, a feature of commodity prices in general, if the price shocks were not initially assumed to have positive autocorrelation. Using more powerful econometric estimation techniques to fit the competitive storage model directly to the price data, Deaton and Laroque [8] found that in case of i.i.d. shocks, the one-period-ahead data did not match with the corresponding predicted values. Contrary to this, their findings showed that a simple first-order autoregression model generates better predictions than the storage model.

Deaton and Laroque [9] deviated from their earlier held logic that speculative storage or inventories account for the short run commodity price dynamics, and instead focused on factors that influence the long run behavior of commodity prices. They postulated that demand, rather than speculative storage is more likely to be a cause of the high autocorrelation found in the commodity prices. On the supply side, they adopted the Lewis [10] model, according to which in the long run the supply is infinitely elastic. With these assumptions, Deaton and Laroque [9] derived a vector error correction model (VECM) to relate commodity price, production and the world income, represented by the gross domestic product (GDP) of the United States (US). Ghoshray and Perera[11] revisited the Lewis model to formulate a nonlinear model of commodity prices. They modified the supply function adopted in the Lewis model by incorporating exponential smooth transition autoregressive (ESTAR) adjustments to arrive at a nonlinear price process. In addition, they used more up to date commodity market data and carried out advanced econometric tests to support the nonlinear price behavior advocated in their paper. Their proposed nonlinear tests outperformed the empirical findings of Deaton & Laroque, [9] that assumes a linear price process.

This paper examines the time series behaviour of price and production data corresponding to four agricultural commodities and four metals in the Indian commodity market with a view to identify their true characteristics. The methodologies followed include standard unit root and co-integration tests to check for the stationarity of the considered time series data and to check for co-integration between the production of each of the commodities and the Indian GDP. Thereafter, parameters of a VECM formulation of the Lewis model [9] are estimated to verify whether this can be used to represent the commodity market data under study. Thereafter, results of advanced unit root tests as well a popular test of stationarity are presented to establish the true characteristics of the commodity prices.

METHODOLOGIES

Basic time series characteristics of the commodity market data and Indian GDP are extracted by applying simple and multiple regression analyses. Growth rates are estimated by expressing the compound interest formula as a regression equation to facilitate the estimation of the standard errors along with the Newey-West corrected standard errors of the estimates using the available functions in the econometric toolbox designed for the Matlab software package [12]. The methodologies used to ascertain the stationarity of the time series under study are briefly outlined below.

Tests of Stationarity

A process is said to be stationary if the mean and the variance are constants over time and the value of the covariance between any two periods, *t* and *t+l*, depends only on the lag between the two time periods. Stationarity of a time series assumes significance in that it helps us to predict or forecast the future value of the time series data only by making observations for a specific period. Study of stationarity of any time series may start with simple observations regarding the nature or trend exhibited by the time series data. Actually, the standard procedures for establishing the stationarity of a process try to reject the null of the presence of a unit root, which makes a time series nonstationary.

The Dickey and Fuller (DF) test

The Dickey-Fuller test for checking the stationarity of a process [13] proceeds as follows:

First, it is decided from a graphical analysis of y_t, the time series variable, whether the underlying process can be modeled as a simple random walk, as a random walk with drift, or as a random walk with drift and trend. This helps in deciding which of the following three equations to estimate via ordinary least square (OLS) regression:

$$\Delta y_t = \delta y_{t-1} + \varepsilon_t \tag{1}$$

$$\Delta y_t = \beta_1 + \delta y_{t-1} + \varepsilon_t \tag{2}$$

$$\Delta y_t = \beta_1 + \beta_2 t + \delta y_{t-1} + \varepsilon_t \tag{3}$$

where β_1 and β_2 and δ are constants and *t* is the time variable representing the existence of a trend, and ε_t follows a stochastic process with zero mean and constant variance. As shown by Dickey and Fuller [13], the coefficient δ follows the 'tau' statistics, which has critical values computed on the basis of Monte Carlo simulations.

Augmented Dickey-Fuller test

In conducting the Dickey-Fuller test it is assumed that the OLS regression technique will give a true estimate of the regression coefficient. However, one of the main assumptions behind the OLS technique to give true estimates of the regression coefficients is that the error terms are uncorrelated. In order to cancel possible autocorrelation in the error terms, another test of stationarity known as the augmented Dickey Fuller (ADF) test may be used. This augments the regression equations to be estimated by adding the lagged values of the dependent variable to the right hand side.

Thus, the regression equation to be estimated is one of the following equations.

$$\Delta y_t = \delta y_{t-1} + \sum_{l=1}^{L} \alpha_l \Delta y_{t-l} + \varepsilon_t \qquad (4)$$

$$\Delta y_t = \beta_1 + \delta y_{t-1} + \sum_{l=1}^{L} \alpha_l \Delta y_{t-l} + \varepsilon_t \qquad (5)$$

$$\Delta y_t = \beta_1 + \beta_2 t + \delta y_{t-1} + \sum_{l=1}^{L} \alpha_l \Delta y_{t-l} + \varepsilon_t \qquad (6)$$

In Equations (4), (5) and (6) the value of L, the maximum lag to be used, is determined empirically to nullify any autocorrelation present in the error terms.

Kapetanios, Shin and Snell Unit Root Test

The Kapetanios, Shin and Snell unit root test (subsequently referred to as the KSS test) extends the ADF test by accounting for the presence of exponential smooth transition autoregressive (ESTAR) adjustments in the time series data[14]. The null hypothesis for this test is the presence of a unit root against the alternative hypothesis of the series being stationary under ESTAR adjustments. In the following, the methodology followed by Kapetanios et al. [14] to arrive at the test statistics is briefly outlined.

In an ESTAR framework, Equation (1) can be expressed as follows:

$$\Delta y_t = \gamma \left[1 - \exp(-\theta y_{t-1}^2) \right] + \varepsilon_t \qquad (7)$$

The null hypothesis here is H_0 : $\theta = 0$ and the alternative hypothesis is H_1 : $\theta > 0$. Testing the null hypothesis directly is not feasible as it is not possible to determine the coefficient γ under the null. Therefore, by using a Taylor series approximation in Equation (7), Kapetanios et al.[14] derived the following regression equation.

$$\Delta y_t = \delta y_{t-1}^3 + \varepsilon_t \qquad (8)$$

In order to take care of the possible autocorrelation, Equation (8) is augmented with lagged values of the dependent variable to get

$$\Delta y_t = \delta y_{t-1}^3 + \sum_{l=1}^{L} \alpha_l \Delta y_{t-l} + \varepsilon_t \qquad (9)$$

Kapetanios et al. [7] showed that the test statistics does not follow the asymptotic normal distribution. Rather, the asymptotic critical values are obtained with the help of extensive simulation. These critical values are presented in the appendix.

Kwiatkowski–Phillips–Schmidt–Shin Test

In each of the DF, ADF and KSS tests, the null hypothesis is the presence of a unit root that makes the process non-stationary. Contrary to this, the null hypothesis in the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test is that a given time series is stationary around a deterministic trend .This test is generally used along with unit root tests to differentiate between the series that appear to be stationary and the series that appear to have a unit root. Also, one can determine whether the available series lacks sufficient information or the tests are not able to give concrete information regarding the stationarity of the series.

Generalized Least Square Based Nonlinear Unit root Tests

The Generalized Least Square (GLS) based nonlinear unit root tests, advocated by Kapetanios and Shin[15] are deemed to be more efficient and have higher power compared to the standard ADF unit rot tests. This test simply involves applying the ADF test to the original time series that is first demeaned or detrended by applying the GLS procedure. Using extensive stocastics simulation, Kapetanios and Shin [15] have estimated and reported the critical values for the test statistics obtained through this procedure.

Cointegration Test

Two economic variables are said to be co-integrated if they are related to each other, or there is existence of proportionate variation between the variables. More formally, the economic variables X_t and Y_t are said to be co-integrated, if they can be related as follows:

$$Y_t = \beta_1 + \beta_2 X_t + \varepsilon_t \qquad (10)$$

where β_2 is called the co-integration parameter.

It is observed in economic theory that two presumably $I(1)$ variables may be co-integrated [13], or there may exist a specific relationship between them. One can verify for the existence of co-integration between these two variables simply by regressing one of the variables against the other and by significance testing of the regression parameter β_2. However, this may be a case of spurious regression, which implies that though the two $I(1)$ processes or variables are not correlated, it seems that a statistical relationship exists between them.

Engle-Granger test for co-integration

A test for co-integration between two variables is based upon the following reasoning: if the nonstationary variables are not co-integrated, a linear combination of them will be nonstationary and hence the residuals u_t, $1 \le i \le N$, obtained by regressing one on the other will be nonstationary; hence, these would have a unit root [13, 16]. So, if the residuals are found to have a unit root, it points to the fact that the variables may not be co-integrated. On the other hand, if the residuals do not have a unit root then it can be concluded that the two variables are co-integrated. Hence, the test proceeds as follows:

- Regress one variable against the other and obtain the residuals $\varepsilon_t, 1 \le t \le N$.
- Use the ADF test, with a particular number of lag terms for $\Delta\varepsilon_t$, and estimate the parameter $(\rho - 1)$ and the corresponding t-value for the hypothesis that the parameter will be zero.
- Compare these t-values with certain critical t-values for hypothesis testing. These critical values are different from the standard DF t-values as they involve an estimated parameter.

Lewis Model

The Lewis model tried to explain the fact that, “in spite of technical progress in the industry, the price of West Indian sugar persistently declined relative to the prices of imported manufactured goods.” Lewis argued that as long as there is unlimited supply of labor at the minimum wage, the prices of world sugar would not rise. Rather it might decline with technical progress.

Deaton and Laroques’ formulation of the Lewis model [9] assumed that the commodity supply is infinitely elastic in the long run and that the excess of current price over the long run supply price influences the rate of growth of supply. It is assumed that the demand for a commodity is linked to the level of world income, given by the GDP, and to the price of the commodity. The commodity price is assumed to be stationary around its supply price, and commodity supply and world income are assumed to be co-integrated. There being long lags in supply, the price process is predicted to slowly revert to its mean. Further, it is assumed that in the short run, prices are driven by fluctuations in the income, but become stationary over a longer period.

Using the Lewis model Deaton and Laroque [9] derived the following VECM to relate the commodity price, production, and the world income.

$$\Delta q_t = b_{q0} + b_{q1}(\theta y_{t-1} - q_{t-1}) + B_{qq}(L)\Delta q_{t-1} + B_{qp}(L)p_{t-1} + B_{qy}(L)\Delta y_{t-1} + \varepsilon_t^q \quad (11)$$

$$p_t = b_{p0} + b_{p1}(\theta y_{t-1} - q_{t-1}) + B_{pq}(L)\Delta q_{t-1} + B_{pp}(L)p_{t-1} + B_{py}(L)\Delta y_{t-1} + \varepsilon_t^p \quad (12)$$

$$\Delta y_t = b_{y0} + b_{y1}(\theta y_{t-1} - q_{t-1}) + B_{yq}(L)\Delta q_{t-1} + B_{yp}(L)p_{t-1} + B_{yy}(L)\Delta y_{t-1} + \varepsilon_t^y \quad (13)$$

In the above equations, p_t, q_t, y_t, Δq_t and Δy_t denote the price, production, and income and the first differences of the production and income data respectively.

Ghoshray and Parera[11]) revisited the Lewis model and examined the commodity market data by introducing nonlinearities in the price and supply equations in the form of ESTAR adjustments. With this assumption, the commodity price, production and GDP series were found to be related through the following equation.

$$\Delta q_t = \delta p_{t-1}^3 + \beta \Delta y_{t-1} + \varepsilon_t \quad (14)$$

From the above equation, the t-statistics was computed for the null hypothesis of no co-integration, i.e., $H_0 : \delta = 0$, the alternative hypothesis being $H_1 : \delta < 0$, for nonlinear ESTAR co-integration. As stated by Ghoshray and Parera [11], the test has better size and power properties compared to the standard tests of co-integration like the Engle-Granger test.

Sources and Nature of Data

The Indian commodity market data used to address the various objectives are of secondary nature and are obtained from the Multicommodity Exchange (MCX), India, accessed through the Internet site *Indiainfoline.* The consumer price index (CPI) data used to deflate the commodity prices are collected from the from the website of Central Statistical Organization, Ministry of Statistics and Programme Implementation, Government of India. The commodity market data used in this study correspond to a period ranging from April 1993 to November 2007. Price and production data for four agricultural commodities, viz. sugar, tea, rubber and cotton, and four metals viz., copper, zinc, lead, and aluminum are used in the analyses. The above Internet site enlists the monthly data corresponding to the mentioned commodity prices in INR/ton and production in thousand metric tons. From the available data quarterly averages are computed and used in the analyses. The data used are available on monthly basis from which quarterly averages are computed and then these are used in the analyses. The Indian GDP data for the period 1996-97 (1st quarter) to 2005-06 (2nd quarter) are collected from Gujrati and Sangeetha [13] Annual GDP growth rates of 7.2%, 8%, 7.8%, 9.4%, and 8.9%

are used for the years 1994, 1995, 1996, 2006, and 2007 respectively to estimate the rest of the quarterly average GDP values.

General Behavior and Descriptive Statistics of Indian Commodity Market Data

The commodity prices under study are deflated by the Indian consumer price index (CPI) so that their real growth patterns may be uncovered, stabilizing any random fluctuations such as seasonal variations that affects agricultural commodity prices. In order to get a preliminary idea about the variations in data under the current study, the log of deflated average quarterly prices are first plotted in Figure 1 and Figure 2 for the four agricultural commodities and the four metals respectively. The log of the corresponding production data are plotted in Figure 3 and Figure 4. Figure 5 finally plots the log of average Indian GDP for the respective quarters. Similar to the observation made by Deaton and Laroque [9] for international commodity prices, in the present study also it is found that the trends are relatively smaller than the variability in the respective series. Moreover, it is found that the deflated prices have a downward trend in general. In contrast, commodity production and GDP are observed to have a lot of variability. Further, the GDP as well as the production data, especially for the metal commodities, are observed to have an upward trend. From these figures it may be commented that commodity prices are stationary in nature, whereas commodity production and GDP, which is taken to represent the income, have nonstationary characteristics.

Table 1 compiles the descriptive statistics for the average quarterly commodity market data and the quarterly Indian GDP series considered in this study. The statistics include the mean, standard deviation, coefficient of skewness, and excess kurtosis exhibited by the log of the respective series. Along with the skewness and kurtosis of each of the commodity market and GDP series, the corresponding test statistics are given that indicate how many standard errors separate the sample skewness or excess kurtosis from zero. The test statistics are computed as follows:

For series with *n* observations, the standard error of skewness is given by,

$$SES = \sqrt{\frac{6n(n-1)}{(n-2)(n+1)(n+3)}}\,.$$

The test statistics is then given by $Z_1 = \gamma$ /SES [17]

Similarly, the standard error of kurtosis for a series with *n* elements is gven by,

$$SEK = 2(SES)\sqrt{\frac{n^2-1}{(n-3)(n+5)}}\,.$$

The test statistics for excess kurtosis is given by $Z_2 = \kappa$ /SEK.

The critical values of each of the above test statistics at 5 percent level of significance is approximately 2.0[17]. The Jarque Bera statistics for normality of the series are also presented in Table 1 along with the corresponding p-values.

It is found that each of the production series in general has higher variability than the corresponding price series. This might be attributed to shocks such as weather-related shocks for the agricultural commodities and shocks due to variations in demand and supply factors for metals. Following observations are made regarding the higher order moments, that is, skewness and kurtosis, which indicate how much a time series deviates from a normal distribution. According to Bulmer [18], a rule of thumb to interpret the coefficient of skewness γ is that if $|\gamma|$ is greater than 1, the distribution is highly skewed, if 0.5 < $|\gamma|$ <1 the distribution is moderately skewed, and if $|\gamma|$ < 0.5 the distribution is considered to be approximately symmetric.

From Table 1, it is observed that the sugar and rubber price series are approximately symmetric whereas the other two agricultural price series are moderately skewed. Further, only the cotton price series is found to have moderate negative skewness, the rest of the agricultural commodities exhibiting positive skewness. Also, from the test statistics it can be said that the population is very likely to be positively skewed only for tea. On the other hand, regarding the price series of metals considered in this work, it can be said that these exhibit moderate positive skewness. From the test statistics, it may be concluded that each of the corresponding populations is likely to be positively skewed. The production data corresponding to the agricultural commodities, except cotton, exhibit significant positive or negative skewness. However, from the statistics obtained for the production data of metals, it is not possible to draw any conclusion regarding the skewness of the corresponding population.

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Table 1: Descriptive Statistics for Log Price and Production Data in the Indian Commodity Market and the Indian GDP

Commodity	Period	Sample size	Mean	Stan. Dev.	Coeff. of Skewness	Coeff. of Kurtosis	JB Stat.	p-value
Prices								
Sugar	Apr.’93-Jun.’07	57	3.71	0.19	0.04 (0.13)	-0.38 (-4.56)	0.36	0.83
Tea	Apr.’97-Dec.’07	43	5.10	0.18	0.76 (2.10)	0.19 (1.74)	4.18	0.12
Rubber	Apr.’95-Sept.’07	50	4.79	0.34	0.21 (0.62)	-1.30 (-13.75)	3.81	0.15
Cotton	Jan.’98-Sep,’04	27	5.61	0.07	-0.64 (-1.43)	-0.87 (-5.09)	2.67	0.26
Copper	Apr.’95-Sept.’07	50	6.04	0.27	0.71 (2.11)	-0.77 (-8.14)	5.48	0.06
Zinc	Apr.’95-Jun.’07	49	5.45	0.29	0.75 (2.21)	-0.02 (-0.21)	4.28	0.12
Lead	Apr.’95-Sept.’07	50	4.82	0.21	0.74 (2.20)	-0.12 (-1.27)	4.62	0.10
Aluminium	Apr.’95-Sept.’07	46	11.45	0.18	0.82 (2.34)	0.04 (0.39)	5.21	0.07
Production								
Sugar	Apr.’93-Jun.’ 07	57	13.46	1.42	0.74 (2.34)	-0.68 (-8.17)	6.25	0.04
Tea	Apr.’97-Dec.’07	43	11.09	0.54	-1.00 (-2.77)	-0.44 (-4.02)	7.58	0.02
Rubber	Apr.’95-Jun.’07	49	10.88	0.19	0.75 (2.21)	-0.52 (-5.39)	5.10	0.08
Cotton	Jan.’98-June’07	46	12.45	0.04	-0.65 (-1.86)	-0.80 (-7.80)	2.62	0.27
Copper	Apr.’95-Sept.’07	50	10.01	1.25	-0.26 (-0.77)	-0.58 (-6.13)	1.27	0.53
Zinc	Apr.’96-Sept.’07	46	9.80	0.32	0.44 (1.26)	-0.39 (-3.80)	1.79	0.41
Lead	Apr.’95-Sept.’07	50	8.22	0.77	0.50 (1.49)	-0.14 (-1.48)	2.08	0.35
Aluminium	Apr.’96-Sept.’07	46	10.98	0.29	0.53 (1.51)	-0.88 (-8.58)	3.65	0.16
Indian GDP	Apr.’93-Dec.’ 07	59	8.43	0.29	0.31 (1.00)	-0.78 (-6.69)	2.43	0.30

As far as excess kurtosis is concerned, it is observed that all of the agricultural commodities prices except tea have negative excess kurtosis or the series are platykurtic. The corresponding test statistics, except that for tea, are found to be significant at the 5 percent level. So far as the metals are concerned, all of these exhibit negative kurtosis and except for lead, the related test statistics are found to be significant at the 5 percent level. The GDP series also exhibits significant negative kurtosis. The departure from normality of most of the series are also evident from the Jarque-Bera test statistics presented in Table 1.

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Table 2: Autocorrelation estimates for log of price data in the Indian commodity market

Comm.	Sugar			Tea			Rubber		
Lag	ACF	Q-Stat	Pr.	ACF	Q-Stat	Pr.	ACF	Q-Stat	Pr.
1	0.87	45.70	0	0.65	19.64	0	0.90	42.12	0
2	0.76	81.05	0	0.46	29.45	0	0.81	76.69	0
3	0.67	109.05	0	0.35	35.32	0	0.72	104.67	0
4	0.62	133.26	0	0.43	44.68	0	0.62	125.80	0
5	0.53	151.45	0	0.31	49.45	0	0.48	138.67	0
6	0.46	165.68	0	0.28	53.41	0	0.36	146.30	0
7	0.41	176.95	0	0.17	55.00	0	0.26	150.50	0
8	0.39	187.37	0	0.19	57.00	0	0.19	152.61	0
Comm.	Cotton			Copper			Zinc		
Lag	ACF	Q-Stat	Pr.	ACF	Q-Stat	Pr.	ACF	Q-Stat	Pr.
1	0.85	21.53	0	0.89	42.05	0	0.91	40.26	0
2	0.65	34.76	0	0.75	72.46	0	-0.24	70.55	0
3	0.45	41.33	0	0.63	94.41	0	-0.27	89.61	0
4	0.25	43.45	0	0.52	109.64	0	-0.09	99.56	0
5	0.07	43.64	0	0.39	118.33	0	-0.13	103.03	0
6	-0.11	44.07	0	0.28	123.03	0	0.03	103.57	0
7	-0.21	45.00	0	0.21	125.59	0	0.12	103.58	0
8	-0.25	48.28	0	0.12	126.45	0	0.09	103.87	0
Comm.	Lead			Aluminium					
Lag	ACF	Q-Stat	Pr.	ACF	Q-Stat	Pr.			
1	0.86	38.85	0	0.92	41.61	0			
2	0.72	66.60	0	0.81	74.56	0			
3	0.61	87.07	0	0.70	99.72	0			
4	0.49	100.86	0	0.59	117.83	0			
5	0.39	109.88	0	0.48	130.12	0			
6	0.30	115.30	0	0.37	137.79	0			
7	0.23	118.43	0	0.29	142.60	0			
8	0.17	120.23	0	0.25	146.23	0			

Table 2 presents the autocorrelation statistics for the eight commodity price series under the present study and Table 3 presents the autocorrelation statistics for the commodity production and the Indian GDP. The corresponding Q-statistics (Q-stat) and probabilities (Pr.) are also presented. It is observed that each of the commodity prices excepting tea price exhibit a high degree of autocorrelation. This is in agreement with the general behaviour of commodity prices [9].

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Table 3: Autocorrelation estimates for log of production data in the Indian commodity market and the Indian GDP

Comm.	Sugar			Tea			Rubber		
Lag	ACF	Q-Stat	Pr.	ACF	Q-Stat	Pr.	ACF	Q-Stat	Pr.
1	0.01	0.0032	0.96	-0.07	0.25	0.6	-0.07	0.26	0.61
2	-0.71	30.45	0	-0.71	24.0	0	-0.43	10.46	0.01
3	-0.02	30.48	0	-0.11	24.5	0	-0.04	10.53	0.02
4	0.84	75.61	0	0.89	64.1	0	0.83	49.24	0
5	-0.06	75.82	0	-0.06	64.3	0	-0.06	49.44	0
6	-0.69	107.01	0	-0.64	86.0	0	-0.46	61.49	0
7	-0.08	107.43	0	-0.10	86.5	0	-0.11	62.20	0
8	0.72	143.07	0	0.79	120.7	0	0.73	95.04	0
Comm.	Cotton			Copper			Zinc		
Lag	ACF	Q-Stat	Pr.	ACF	Q-Stat	Pr.	ACF	Q-Stat	Pr.
1	0.74	16.48	0	0.63	21.27	0	0.85	35.47	0
2	0.53	25.15	0	0.60	40.69	0	0.76	64.66	0
3	0.29	27.95	0	0.52	55.90	0	0.69	88.97	0
4	0.14	28.68	0	0.68	82.29	0	0.62	109.49	0
5	-0.03	28.72	0	0.53	98.51	0	0.52	124.04	0
6	-0.06	28.84	0	0.45	110.38	0	0.44	134.70	0
7	-0.17	29.98	0	0.37	118.47	0	0.35	141.66	0
8	-0.23	32.08	0	0.40	128.60	0	0.34	148.40	0
Comm.	Lead			Aluminium			Indian GDP		
Lag	ACF	Q-Stat	Pr.	ACF	Q-Stat	Pr.	ACF	Q-Stat	Pr.
1	-0.03	0.07	0.80	0.90	39.80	0	0.85	51.30	0
2	-0.06	0.25	0.88	0.83	74.02	0	0.71	87.22	0
3	-0.11	0.94	0.81	0.74	102.40	0	0.77	130.13	0
4	0.42	10.93	0.03	0.68	126.49	0	0.83	180.91	0
5	0.09	11.44	0.04	0.59	145.23	0	0.69	217.11	0
6	-0.18	13.46	0.04	0.51	159.54	0	0.56	241.43	0
7	-0.23	16.71	0.02	0.44	170.62	0	0.60	269.53	0
8	-0.06	16.91	0.03	0.40	179.85	0	0.64	302.24	0

From Table 3 it is observed that except for cotton, the production series for the other agricultural commodities exhibit negligible autocorrelation. Out of the metals considered, only lead shows a low degree of negative autocorrelation. The other three commodity production series and the Indian GDP series exhibit high and significant positive autocorrelation.

RESULTS of ANALYSES in a LINEAR FRAMEWORK

Table 4 presents the mean growth rates of the commodity price and production series as well as of the quarterly Indian GDP. The table also lists the standard errors of the estimates as well as the Newey-West corrected standard errors. It is observed that all the agricultural commodity prices and aluminium prices have negative growth rates, i.e., there is a declining trend in the prices of these commodities. However, the rate of decline in each case is found to be rather small. Moreover, all the rates of decline, except for sugar, are seen to be less than the standard errors of these estimates. The large standard errors are due to the high variability in the price series.

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Table 4: Growth Rates of Price and Production of a Few Selected Commodities and the Indian GDP

Commodity	Mean growth rate	Standard error	Corrected standard error
Prices			
Sugar	-0.011	0.009	0.008
Tea	-0.010	0.018	0.008
Rubber	-0.007	0.015	0.021
Cotton	-0.002	0.008	0.006
Copper	0.002	0.014	0.017
Zinc	0.007	0.013	0.016
Lead	0.018	0.016	0.018
Aluminium	-0.005	0.014	0.007
Production			
Sugar	0.028	0.270	0.079
Tea	0.010	0.113	0.032
Rubber	0.009	0.036	0.012
Cotton	0.009	0.005	0.004
Copper	0.027	0.154	0.046
Zinc	0.029	0.016	0.008
Lead	0.017	0.179	0.040
Aluminium	0.023	0.010	0.006
Indian GDP	0.018	0.015	0.005

The lack of significant trends is consistent with the general view that commodity prices are stationary in nature. However, as stated in Deaton and Laroque [9]) without further analysis, only based on these results it is not possible to reject the alternative hypothesis that prices are nonstationary. The average quarterly production data for all the commodities and the Indian GDP are observed to exhibit small, but positive growth rates. Further, the growth rates are found to be smaller than the standard errors for all the agricultural commodities except cotton. On the other hand, for zinc and aluminium, the production data are found to have small and significant positive growth rates. Both copper and lead have small positive growth rates, although not significant (much smaller than their standard errors).

Results of Standard Unit Root Tests

In order to check for stationarity of the commodity market data, first the equations presenting the Augmented Dickey Fuller test, i.e., Equation (3.13) or Equation (3.14) of Chapter 3 are estimated using ordinary least square regression (OLS regression). Then, the t-statistics computed by dividing the estimated coefficients of y_{t-1} by the corresponding standard errors, and the computed t-statistics are compared with the critical t-values corresponding to 5 percent confidence level. If the computed t-value exceeds the critical t-value then the time series is considered to be stationary and the null hypothesis, i.e., $\delta = 0$ is rejected. On the other hand, if the computed t-value is less than the critical t-value in absolute terms, the null hypothesis is not rejected, which implies that the time series may be non-stationary. As the first difference of this process is stationary, it is an $I(1)$ process.

Table 5 presents the results of ADF test on price and production data corresponding to the selected commodities. The model chosen includes only drift and the one-period lagged value. Table -6, on the other hand, presents the results obtained by estimating the model that includes both drift and trend terms in addition to the one-period lagged value. It may be mentioned here that selecting an appropriate regression model is highly significant while conducting the unit root test. The critical t-values also differ for the two models. Table -5 also lists the F-values computed under the restriction that both the constant term and the coefficient of the lagged logarithm are zeros. Similarly, Table 4.6 lists the F-values computed under the restriction that the constant term, coefficient of the lagged logarithm, and the trend term are zeros.

Three different hypotheses are tested by comparing the computed t-values or F-values against the critical values (listed either in the standard t-table or nonstandard t-values). These are: H1 – coefficient on the lagged logarithm is zero assuming a non zero constant term; H2 – the coefficient on the lagged logarithm is zero assuming the presence of either only a drift, or both drift and a trend; and H3 – the joint hypothesis that the constant term as well as the coefficient of the lagged logarithm (and trend) are zeros. The first two hypotheses are tested by comparing the computed t-values against the standard or non-standard critical t-values, and the third hypothesis is verified by comparing the computed restricted F-values against the critical DF F-values. These critical values are presented in Appendix A.

Table 5 and Table 6 both indicate whether the hypotheses H1, H2, or H3, are rejected (×) or not rejected (√). The critical t-value for testing the hypothesis H1 at 5 percent significance level is 1.96. For a sample size of 50, the critical DF t-value to test the null of *I*(*1*) under the hypothesis H2, at 5 percent level of confidence level, is -2.93 for the model with drift only and -3.5 for the model with both drift and trend. For a sample size of 25, the critical DF t-values are -3.0 and -3.6 respectively. For a sample size of 25, the critical F-value at 5 percent confidence level for verifying the joint hypothesis that both the constant and coefficient of Y_{t-1}, or the constant, coefficient of Y_{t-1}, and the trend are zero, is 5.68. For a sample size of 50, the critical F-value is 5.13. These critical values are used to arrive at the conclusions listed in columns H1, H2, and H3 of both Table 5 and Table 6.

Table 5: Standard Unit Root Test for Price and Production of a Few Selected Commodities (With Drift Only)

Commodity	Constant	SE	ρ-1	SE	t-value	F-value	H1	H2	H3
Prices									
Sugar	0.36	0.27	-0.08	0.06	-1.36	1.92	√	√	√
Tea	1.35	0.55	-0.23	0.09	-2.54	5.76	×	√	×
Rubber	0.66	0.33	-0.11	0.06	-2.05	2.10	×	√	√
Cotton	0.10	2.02	-0.02	0.30	-0.06	0.54	√	√	√
Copper	0.45	0.45	-0.07	0.08	-0.98	0.57	√	√	√
Zinc	0.81	0.40	-0.15	0.07	-2.02	2.11	×	√	√
Lead	-0.03	0.33	0.01	0.07	0.14	0.49	√	√	√
Aluminium	1.94	0.69	-0.35	0.13	-2.82	4.05	×	√	√
Production									
Sugar	6.84	3.85	-0.47	0.26	-1.76	1.84	√	√	√
Tea	2.89	2.23	-0.24	0.18	-1.29	1.22	√	√	√
Rubber	0.92	0.59	-0.07	0.05	-1.53	2.57	√	√	√
Cotton	-0.62	1.59	0.05	0.12	0.40	0.94	√	√	√
Copper	1.19	1.07	-0.10	0.11	-0.91	2.12	√	√	√
Zinc	-0.31	0.65	0.04	0.07	0.54	1.56	√	√	√
Lead	4.68	2.97	-0.56	0.36	-1.56	1.27	√	√	√
Aluminium	-0.15	0.51	0.02	0.05	0.35	1.49	√	√	√
Indian GDP	-0.08	0.09	0.01	0.01	1.04	3.89	√	√	√

Table 6: Unit Root Test for Price and Production of a Few Selected Commodities (With Drift and Trend)

Commodity	Constant	SE	ρ-1	SE	t-values	F-value	H1	H2	H3
Prices									
Sugar	1.53	0.54	-0.3	0.11	-2.87	5.22	×	√	×
Tea	1.56	1.40	-0.26	0.22	-1.20	5.58	√	√	×
Rubber	0.73	0.30	-0.14	0.05	-2.77	6.50	√	√	×
Cotton	8.12	3.44	-1.19	0.51	-2.36	4.37	√	√	√
Copper	0.07	0.45	-0.03	0.07	-0.38	3.81	√	√	√
Zinc	0.87	0.46	-0.16	0.08	-1.93	2.09	√	√	√
Lead	-0.37	0.32	0.06	0.06	0.95	4.90	√	√	√
Aluminium	1.83	0.72	-0.34	0.13	-2.59	4.16	×	√	√
Production									
Sugar	7.62	3.89	-0.53	0.27	-1.97	2.58	√	√	√
Tea	16.51	4.57	-1.38	0.38	-3.61	7.00	×	√	√
Rubber	6.89	2.60	-0.58	0.22	-2.64	5.59	×	√	×
Cotton	2.38	2.67	-0.18	0.2	-0.89	1.93	√	√	√
Copper	5.04	2.85	-0.57	0.34	-1.67	3.24	√	√	√
Zinc	4.70	2.16	-0.50	0.23	-2.17	4.71	√	√	√
Lead	4.74	3.62	-0.57	0.42	-1.34	1.23	×	√	√
Aluminium	2.52	1.44	-0.24	0.14	-1.74	3.57	√	√	×
Indian GDP	0.84	1.33	-0.07	0.11	-0.62	4.09	√	√	√

Table 7: Cointegration Test for Production Data of a Few Selected Commodities and Indian GDP

Commodity	θ	ρ-1	Standard Error	t-value
Sugar	2.23	-0.20	0.13	-1.55
Tea	-0.15	-0.18	0.14	-1.28
Rubber	0.70	-0.70	0.29	-2.38
Cotton	0.37	-0.30	0.20	-1.28
Copper	4.16	-0.42	0.27	-1.55
Zinc	1.29	-0.64	0.25	-2.55
Lead	-0.43	-0.61	0.39	-1.56
Aluminium	1.18	-0.39	0.19	-2.12

From Table 5, it is found that for almost half of the commodity prices such as for Tea, Rubber, Zinc, and Aluminium, the hypothesis H1 is rejected, whereas for the other commodity prices it is not. However, for all the commodity prices except for Lead prices, the coefficient of the lagged variable is negative. Even for lead, the coefficient is a very small positive value, much less than the standard error, indicating that by and large the prices in the Indian commodity market can be taken as stationary. This is evident even from the results reported in Table-6, which assumes the presence of a time trend in addition to the drift. Thus, the ADF unit root tests are able to better establish the stationarity of prices in the Indian commodity market better than that found in Deaton and Laroque[9] for prices in the international commodity market.

From the lower half of Table 5 and Table 6, which show the results for production and GDP data, it is found that the drifts in the production and GDP time series are of a greater magnitude and there is a positive drift in all the production data except for Cotton, Zinc, and Aluminium in Table 5. Also, the hypothesis H1 is now rejected only for Tea, Rubber, and Zinc production. For all the other commodities, including the Indian GDP, the hypothesis is not rejected. For Tea Production in Table 5, and for Tea and Rubber production in Table 6, even the F-test rejects the joint hypothesis. Therefore, it is concluded that in general commodity production data, and the Indian GDP in particular, may be represented by a nonstationary process.

Cointegration Test Results

Table 7 presents the results of the Engle-Granger test for the existence of co-integration between the production data corresponding to each of the selected commodities and the Indian GDP. The values of the cointegration parameter (θ) obtained while regressing the log of production data of each of the commodities on the log of Indian GDP are reported. An ADF test with five different lags is conducted on the residuals obtained from each regression (Gujrati and Sangeetha, 2007) and results of this test are presented in the table. The critical t-values for the null of no co-integration are different from the standard Dickey Fuller critical values as the residuals involve an estimated parameter. The critical t-values are 3.28, 3.7 and 4.32 at the 10 percent, 5 percent and 1 percent significance levels respectively.

The cointegration parameter θ is found to be greater than one for half of the commodities. Again out of these, θ is found to be a negative value for Tea and Lead, whereas it is estimated to be a small positive number for Cotton. The t-values obtained for the hypothesis, that the coefficient on the lagged logarithm is zero, is found to be less than the critical t-value for all the commodities. This points to the fact that the results obtained by regressing the production data against the GDP may be an outcome of spurious regression. However, five of these coefficients are less than 0.5, indicating that the failure to detect cointegration might be due to the lack of power of these tests[9].

Parameter Estimates for the Lewis Model

It is mentioned earlier that Deaton and Lewis [9] assumed the commodity prices to follow a linear process and further assumed that the amount of commodity production is cointegrated with the income, represented by the GDP. In the present study, the vector error correction model derived by Deaton and Laroque (2003) is fitted to the available data from the Indian commodity market. The corresponding parameters are estimated using the full information maximum likelihood (FIML) technique in GNU regression, econometric and time series library (Gretl). Use of this technique gives the best estimates for the parameters in the Lewis model.

Table 8 and Table 9 respectively compile the parameters of the Lewis model when applied to the eight price and production series under consideration. The first column lists the coefficients of the constant term (const.), the cointegrating term (coin.), the first and second lags of price as well as changes in production and income. The coefficient of determination (R^2) and adjusted R^2 values are also given for each set of estimates.

The coefficient of the cointegration term in the price equation is found to be a small positive quantity for all the agricultural commodities (Table 8). In the production equation, the coefficient of the cointegration term is found to be close to one for sugar and tea, whereas it is 0.35 for cotton. Only for rubber

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production, the coefficient of the cointegration term has a small value. Also, for sugar, tea and cotton the estimated parameters are statistically significant. On the other hand, from Table 9 it is found that the coefficient of the coinegration term in the price equation has a small negative value for each of the commodities. The coefficients of cointegration terms in the production equation however are positive and significantly different from zero for all of the commodities. Contrary to Deaton and Lewis who found at least one of the coefficients to be significantly different from zero, it is found here that apart from the price series of cotton, copper and zinc, at least two of the estimated coefficients of the price and production equations are significantly different from zero. However, it is observed that the VECM formulation of the Lewis model, derived with the assumption of a linear price process, does not fit the Indian commodity market.

RESULTS OF ADVANCED TESTS OF STATIONARITY

In order to ascertain the stationarity of the price series further, analyses are carried out employing more advanced linear and nonlinear unit root tests as well as other tests of stationarity. The advanced linear unit root tests carried out are the generalized least square based Augmented Dickey-Fuller test (ADF-GLS test) that assumes the presence of a drift only, and the ADF-GLS test assuming the presence of both a drift and a trend. The results of these tests are presented in Table -10. The null hypothesis of this test is the presence of a unit root. The critical values for this test at 10 percent and 5 percent levels of significance are respectively -2.74 and -3.03 for the GLS based ADF test with drift and trend [19]. For the GLS-ADF test with drift, only the corresponding p-values are provided. The tests are conducted through the Gretl software package by specifying a maximum lag order of eight and setting the option of automatic lag length selection. If this option is set, the lag length is gradually decreased from the maximum value till the Akaike information criterion, i.e., AIC [20] is satisfied.

Table 8: Parameter Estimates of the Lewis Model for the Four Agricultural Commodities in the Indian Market using the FIML Technique

Comm.	Sugar		Tea		Rubber		Cotton	
	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.
Price								
const.	0.15	0.66	3.86	2.14	1.39	2.12	2.69	1.70
coin.	0.002	0.15	0.19	1.41	0.18	1.72	0.22	1.12
Δq_{t-1}	0.002	0.17	0.09	0.73	-0.11	-0.99	0.62	2.39
Δq_{t-2}	0.02	2.74	0.25	2.29	-0.01	-0.14	0.01	0.05
p_{t-1}	1.15	9.11	0.83	5.31	1.15	6.79	1.09	5.00
p_{t-2}	-0.20	-1.53	-0.12	-0.81	-0.25	-1.60	-0.21	-1.00
Δy_{t-1}	0.06	0.84	0.65	2.53	-0.34	-2.45	0.02	0.45
Δy_{t-2}	0.13	1.62	0.60	-1.33	-0.18	-1.73	-0.03	-0.67
R^2	0.90		0.65		0.93		0.87	
R^2_{adj}	0.89		0.58		0.92		0.81	
Production								
const.	-11.36	-3.89	12.62	4.15	1.23	1.22	2.34	1.84
coin.	0.90	4.63	0.95	4.12	0.17	1.09	0.35	2.28
Δq_{t-1}	-0.08	0.57	-0.64	-2.90	-0.62	-3.60	-0.15	-0.73
Δq_{t-2}	-0.28	-2.58	-0.04	-0.22	-0.25	-1.66	-0.11	-0.50
p_{t-1}	-5.73	-3.64	-0.57	-2.17	-0.05	-0.24	0.37	2.09
p_{t-2}	7.52	4.71	0.39	1.50	0.002	0.01	-0.19	-1.15
Δy_{t-1}	-4.84	-5.78	4.59	10.61	-0.05	-0.24	-0.03	-0.68
Δy_{t-2}	0.94	0.93	1.65	2.15	1.09	6.89	-0.08	-2.27
R^2	0.87		0.97		0.79		0.42	
R^2_{adj}	0.84		0.96		0.75		0.17	
GDP								
const.	0.01	0.05	0.88	1.51	-0.17	-0.37	-2.37	-0.61
coin.	0.06	0.33	0.06	1.23	-0.02	-0.25	-0.33	-0.69
Δq_{t-1}	-0.002	-0.22	-0.09	-2.19	-0.22	-2.80	0.72	1.13
Δq_{t-2}	0.03	3.36	0.01	0.26	0.06	0.92	-0.44	-0.69
p_{t-1}	-0.13	-1.08	-0.10	-2.02	0.05	0.41	-0.73	-1.37
p_{t-2}	0.13	1.05	0.07	1.33	-0.02	-0.22	0.61	1.19
Δy_{t-1}	-0.18	-2.76	0.31	3.75	-0.14	-1.46	-0.04	-0.34
Δy_{t-2}	-0.74	-9.24	-0.62	-4.18	-0.74	-10.4	-0.87	-8.35
R^2	0.88		0.98		0.90		0.89	
R^2_{adj}	0.87		0.97		0.88		0.84	

Table 9: Parameter Estimates of the Lewis Model for the Four Metal Commodities in the Indian Market using the FIML Technique

Comm.	Copper		Zinc		Lead		Aluminium	
	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.
Price								
const.	0.76	1.21	0.52	1.14	0.12	0.28	0.32	0.74
coin.	-0.01	-0.47	-0.09	-0.48	-0.001	-0.05	-0.02	-0.27
Δq_{t-1}	0.01	0.45	-0.07	-0.33	0.01	0.54	-0.09	-0.81
Δq_{t-2}	0.002	0.16	-0.04	-0.23	0.004	0.30	0.49	0.48
p_{t-1}	1.16	7.88	1.22	7.80	1.09	7.70	1.27	8.05
p_{t-2}	-0.23	-1.52	-0.29	-0.76	-0.11	-0.76	-0.30	-1.85
Δy_{t-1}	0.18	1.77	0.09	0.62	0.13	2.09	-0.04	-0.73
Δy_{t-2}	-0.13	-1.25	0.04	0.26	-0.02	-0.32	0.03	0.58
R^2	0.89		0.89		0.89		0.95	
R^2_{adj}	0.87		0.86		0.87		0.94	
Production								
const.	-17.02	-3.10	-0.81	-2.20	13.57	3.14	-0.69	-1.15
coin.	0.89	3.66	0.47	3.20	1.20	4.56	0.41	3.34
Δq_{t-1}	-0.09	-0.42	-0.18	-1.13	0.14	0.64	-0.02	-0.15
Δq_{t-2}	-0.01	-0.10	-0.05	-0.38	0.11	0.73	0.23	1.62
p_{t-1}	-0.50	-0.39	0.33	2.72	0.01	0.01	0.53	2.37
p_{t-2}	-0.38	-0.29	-0.27	-2.11	0.15	0.10	-0.43	-1.90
Δy_{t-1}	-1.92	-2.14	-0.35	-2.96	0.59	0.91	-0.24	-2.78
Δy_{t-2}	-0.74	-0.83	-0.22	-1.78	1.25	1.87	-0.20	-2.34
R^2	0.51		0.46		0.57		0.29	
R^2_{adj}	0.41		0.36		0.49		0.15	
GDP								
const.	0.72	1.26	0.71	2.45	-0.004	-0.01	-0.02	-0.03
coin.	-0.04	-1.52	-0.39	-3.29	0.02	0.58	-0.44	-2.83
Δq_{t-1}	-0.03	-1.19	-0.17	-1.31	0.01	0.56	-0.39	-1.97
Δq_{t-2}	-0.01	-0.75	-0.27	-2.61	0.01	0.89	-0.20	-1.11
p_{t-1}	-0.19	-1.48	-0.15	-1.51	-0.31	-2.14	-0.32	-1.12
p_{t-2}	0.24	1.76	0.11	1.04	0.36	1.33	0.29	0.99
Δy_{t-1}	0.05	0.54	0.21	2.26	-0.05	-0.80	0.19	1.72
Δy_{t-2}	-0.79	-8.47	-0.69	-6.97	-0.89	-13.15	-0.68	-6.51
R^2	0.82		0.88		0.82		0.86	
R^2_{adj}	0.78		0.86		0.79		0.83	

Table 10: Test Statistics of Advanced Linear Unit Root Tests for the Prices of a Few Selected Commodities

Commodity	ADF-GLS with drift only	p-value	ADF-GLS with drift and trend
Sugar	-0.86 (4)	0.35	-3.24 (4)**
Tea	-0.6	0.46	-1.84 (8)
Rubber	-1.31	0.18	-1.79 (4)
Cotton	-2.05 (4)	0.04	-2.85 (4)*
Copper	-1.82 (8)	0.07	-1.97 (8)
Zinc	-1.95 (4)	0.05	-2.15 (4)
Lead	-0.72	0.40	-1.39 (4)
Aluminium	-0.29 (1)	0.58	-2.46 (1)

Note: (i) In the above table '*' indicates rejection of the null hypothesis at the 10% critical level and '**' indicates rejection of the null at the 5% significance level, the critical values being -2.74 and -3.03 respectively.
(ii) The number in parentheses besides the test statistics indicates the number of lags used.

It is found from Table 10 that through the ADF-GLS test with drift only, it is possible to reject the null hypothesis of nonstationarity at 5 percent level only for cotton and zinc price series whereas the null hypothesis is rejected at the 10 percent level for copper. For rest of the commodity prices it is not possible to reject the null even at 10 percent confidence level. Based on the ADF-GLS test that includes a trend in addition to a drift, the null hypothesis is rejected at the 5 percent level for sugar whereas it is rejected at the 10 percent level for cotton. Thus, the GLS based linear unit root tests are not able to establish the stationarity of all the commodity price series.

Results of the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test, which has a null of stationarity, are presented in Table-11. Both the options of carrying out the test with drift only and conducting the test with drift and trend components are used. The critical values for the first case at the 10 percent, 5 percent, and 1 percent levels are 0.347, 0.463, and 0.739 respectively and the critical values of the test in the second case at the three significance levels are 0.119, 0.146, and 0.216 respectively. The lag truncation parameter is chosen in each case using the formula, $L=\left\lfloor 4\times(T/100)^{1/4}\right\rfloor$ where T is the length of the series and $\lfloor . \rfloor$ denotes the floor operation [21].

From the test results it is observed that with the KPSS test with drift, stationarity can be rejected even at the 1 percent level for prices of both sugar and aluminium whereas it is possible to reject stationarity at the 5 percent level for prices of tea and stationarity can be rejected only at the 10 percent level for cotton. For rest of the commodities, it is not possible to reject the null of level stationarity. From the KPSS test with drift and trend, only for cotton it is not possible to reject the stationarity null. For sugar and aluminium, the null hypothesis can be rejected at the 5 percent level, whereas for rest of the commodities the null hypothesis can be rejected even at the 1 percent level.

The results of KSS nonlinear unit root test [14] and GLS based nonlinear unit root tests [15] are presented in Table 12. The first nonlinear unit root tests adopted in the present study is the KSS test that has a null of a unit root against the alternate hypothesis of stationarity under exponential Smooth Transition Autoregressive (ESTAR) adjustment. In order to conduct this test, Equation (9) is estimated and the corresponding t-values are computed. The critical values for this test at the 10 percent, 5 percent and 1 percent levels of confidence are -1.92, -2.22, and -2.82 respectively for the raw data [15]. For the demeaned data, the corresponding critical values are -3.48, -2.93, and -2.66, and for the detrended data, the critical values at the 10 percent, 5 percent and 1 percent levels of confidence are -3.93, -3.40 and -3.13 respectively. The other nonlinear unit root tests adopted are the KSS test applied to the GLS based demeaned and detrended series. These two GLS based tests are denoted in Table 4.12 as GLS-NL_M test and GLS-NL_T test respectively. The critical values for the first nonlinear unit root test at the 5 percent significance level is -2.21 and that for the second one at the 5 percent significance level is -2.93[15]. Results of the nonlinear cointegration test proposed by Kapetanios et al. [15] are also included in Table -12. These are obtained by estimating Equation (14). This test, which has a null hypothesis of no cointegration against an alternative of nonlinear cointegration under an ESTAR adjustment, is denoted in Table 12 as the NL_ECM test. The critical values for the above test are -2.93, -3.28 and -3.93 at the 10 percent, 5 percent and 1 percent significance level respectively[15].

Table 11: Results of Stationarity Test for The Prices of a Few Selected Commodities

Commodity	KPSS Test with drift only	KPSS Test with drift and trend
Sugar	1.18 (3)***	0.17 (3)**
Tea	0.62 (3)**	0.25 (3)***
Rubber	0.32 (3)	0.31 (3)***
Cotton	0.43 (2)*	0.11 (2)
Copper	0.35 (3)	0.30 (3)***
Zinc	0.23 (3)	0.23 (3)***
Lead	0.32 (3)	0.30 (3)***
Aluminium	1.05 (3)***	0.17 (3)**

Note: In the above table a '*' indicates that the null hypothesis of stationarity may be rejected at the 10% level, a '**' indicates that the null hypothesis may be rejected at the 5% level and a '***' indicates that the null hypothesis may be rejected at the 1% level.

Table 12: Results of Advanced Nonlinear Unit Root Test for the Prices of a Few Selected Commodities

Commodity	KSS Test Statistics	GLS_ NL_M Test Statistics	GLS_ NL_T Test Statistics	NL_ECM Test Statistics
Sugar	-1.28 (0)	-5.51 (1)*	-2.26 (0)	0.67 (8)
Tea	-0.22 (8)	-3.95 (3)*	-4.12 (0)*	2.28 (8)
Rubber	-0.74 (0)	-3.97 (3)*	-4.17 (3)*	-0.77 (6)
Cotton	-0.29 (0)	-9.56 (0)*	-8.60 (0)*	-0.37 (0)
Copper	0.03 (0)	-2.55 (0)*	-2.22 (0)	2.28 (8)
Zinc	-0.22 (0)	-2.52 (1)*	-2.78 (1)	4.20 (3)***
Lead	-0.77 (0)	-1.15 (1)	-1.59 (1)	0.52 (8)
Aluminium	1.85 (0)	-4.82 (0)*	-3.97 (0)*	3.19 (1)*

Note: In the above table a '*' indicates the rejection of the null hypothesis of nonstationarity at the 10% level, '**' indicates the rejection of the null hypothesis at the 5% level and '***' indicates the rejection of the null hypothesis at the 1% level.

Table -13: Consolidated results of test of stationarity and unit root tests

Commodity	KPSS	ADF	ADF_GLS	KSS	GLS_ NL_M	GLS_ NL_T
Sugar	×××	$××_T$	$××_T$	√	××	√
Tea	××	$××_D$	√	√	××	××
Rubber	$√_D$	$××_D$	√	√	××	××
Cotton	$√_T$	√	$××_D$	√	××	××
Copper	$√_D$	√	$×_D$	√	××	√
Zinc	$√_D$	$××_D$	$×_D$	√	××	√
Lead	$√_D$	√	√	√	√	√
Aluminium	×××	$××_T$	√	√	××	××

Note: For the KPSS test in the above table, a '××' indicates that the null of stationarity may be rejected at the 5 percent level and a '×××' indicates that the null may be rejected at the 1 percent level. A '√' indicates that it is not possible to reject the null hypothesis. For all other tests, which are unit root tests, a '×' indicates the rejection of the null hypothesis of the presence of a unit root at the 10 percent level, '××' indicates the rejection of the unit root null at the 5 percent level. A '√', on the other hand, indicates that it is not possible to reject the null hypothesis.

The optimal lag orders at which the test statistics are reported are obtained by following the AIC criteria. It is observed that for none of the commodity price series the KSS test is able to reject the null hypothesis of the presence of a unit root. However, except for the lead price series, the GLS based nonlinear unit root test applied to the demeaned data is able to reject the nonstationarity null in favour of stationarity under an ESTAR adjustment process. The GLS bases nonlinear unit root test applied to the detrended series is able to reject the null hypothesis for price series of tea, rubber, cotton and aluminium. The null hypothesis is rejected by both the tests for the prices of tea, rubber, cotton and aluminium. It may be mentioned here that Ghoshray and Parera [11] were able to establish the stationarity of two out of six commodities when they applied the KSS test, and four commodities when they applied the GLS based nonlinear unit root test to the detrended series. Thus, the results obtained here are consistent with their findings. In addition, it is found that the nonlinear unit root test when applied to the GLS based demeaned data is better able to establish the stationarity of the commodity price series under study. Moreover, the nonlinear cointegration test is found to reject the null hypothesis of no cointegration between the production and GDP for zinc and aluminium.

Table -13 finally presents a consolidated view of the stationarity (or unit-root) test results. For the KPSS test, the null hypothesis is that the series is stationary. For all other tests, the null hypothesis is the presence of a unit root. Therefore, for a stationary series, the KPSS test results should not reject the null hypothesis whereas for all other tests, the null hypothesis should be rejected. On the other hand, for the unit root tests, the null hypothesis should be rejected for a stationary series and not rejected if the series is non-stationary. For the tests with two versions, i.e., that assume the presence of a drift only or the presence of a time trend too, the subscript 'D' and 'T' respectively indicate whether the null hypothesis was rejected or not rejected by the test under the assumption of only a drift or both drift and trend. From these test results, following important conclusions are obtained regarding the characteristics of various commodity prices.

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From the fact that for sugar price series, the unit root null is rejected by both the ADF and ADF-GLS test only by assuming the presence of a time trend, it is concluded that the sugar price series possesses a time trend. However, for sugar price series the KPSS test is not able to provide evidence regarding stationarity of the price series. For the tea price series, although the KPSS test rejects the stationarity null, ADF test rejects the unit root null by assuming the presence of a drift component, whereas the ADF-GLS test is not able to reject the null of non-stationarity. So, it is concluded that stationarity and linear unit root tests are not able to establish the true characteristics of the tea price series. For the rubber price series, both the KPSS test and the ADF test establish the stationarity of the series by assuming the presence of only a drift component. For cotton, whereas the null of the KPSS test is not rejected only if the presence of both drift and trend are assumed, the ADF test applied to the GLS de-demeaned series rejects the unit root null. So, it is not possible to infer anything conclusively regarding the characteristics of the cotton price series. For copper, both the KPSS test and the ADF-GLS test show that the price series is stationary under the assumption of the presence of a drift component only. So, it may be inferred that copper price series is stationary and is devoid of a time trend. Same is also true for the zinc price series. Aluminium price series is found not to possess a unit root as shown by the ADF test results that assumes the presence of a time trend. But, for aluminium, neither the KPSS test, nor the ADF-GLS test is able to establish the stationarity of the price series. Finally, for lead prices, though the null of the KPSS test is not rejected by assuming the presence of a drift, none of the linear unit root tests is able to reject the null of nonstationarity.

CONCLUSIONS

This paper presented results of empirical investigations carried out to ascertain the basic time series characteristics of data corresponding to four agricultural commodities and four metals traded in the Indian commodity market as well as the Indian GDP. It is found that although the ADF unit root test shows the price series to be stationary, the unit root null is rejected only for half of the commodities. The Engle-Granger test also could not establish the presence of cointegration between the production series and the income, represented by the Indian GDP. Further, the empirical results obtained by fitting the Indian commodity market data to the VECM formulation of the Lewis model[9] do not support the underlying assumptions. The results of advanced unit root tests, assuming the commodity price series to follow a nonlinear smooth transition autoregressive process, however, find better evidence of stationarity of the price series as well as cointegration between production and GDP. This motivates one to explore nonlinear modeling approaches such as the smooth transition autoregressive model incorporating generalized autoregressive conditional heteroskedasticity variance terms (STAR-GARCH model) or artificial neural networks to predict future commodity spot prices.

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Appendixes

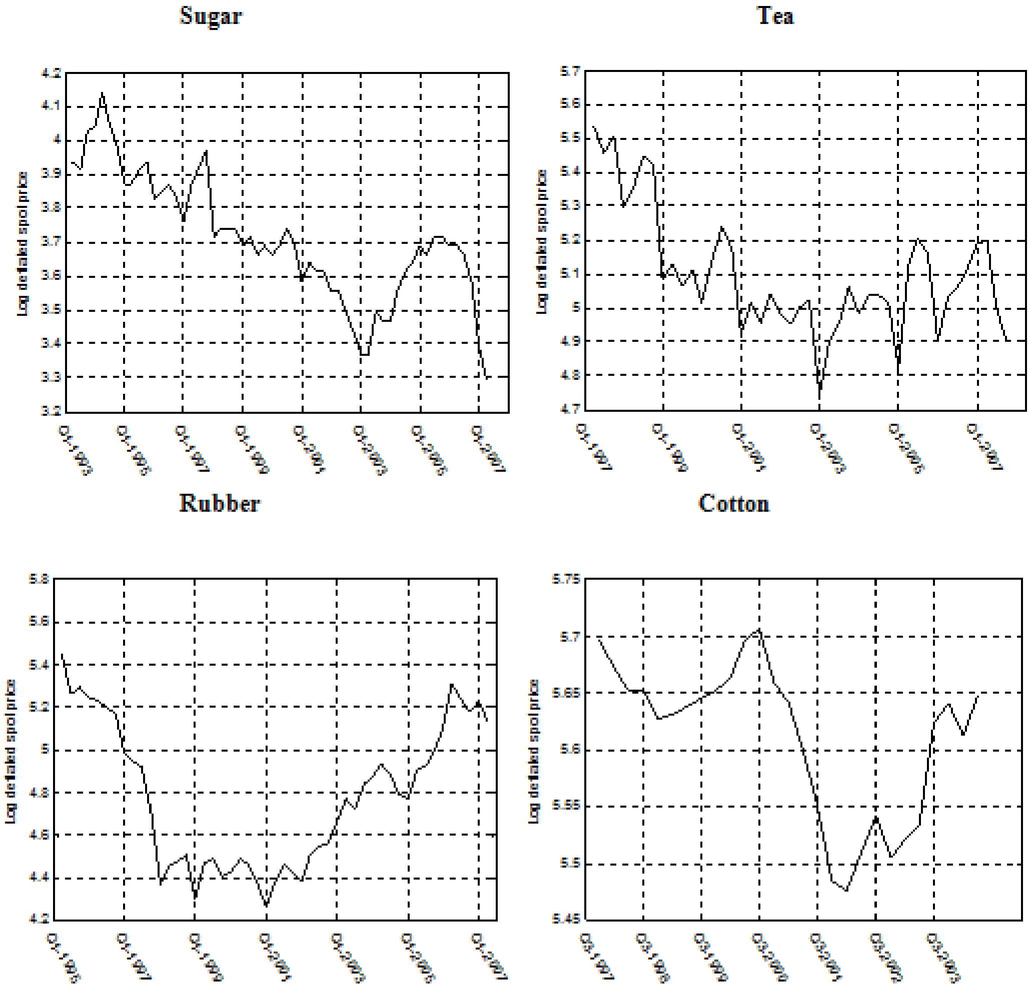

Figure 1: Logarithm of Average Quarterly Deflated Prices of Four Agricultural Commodities

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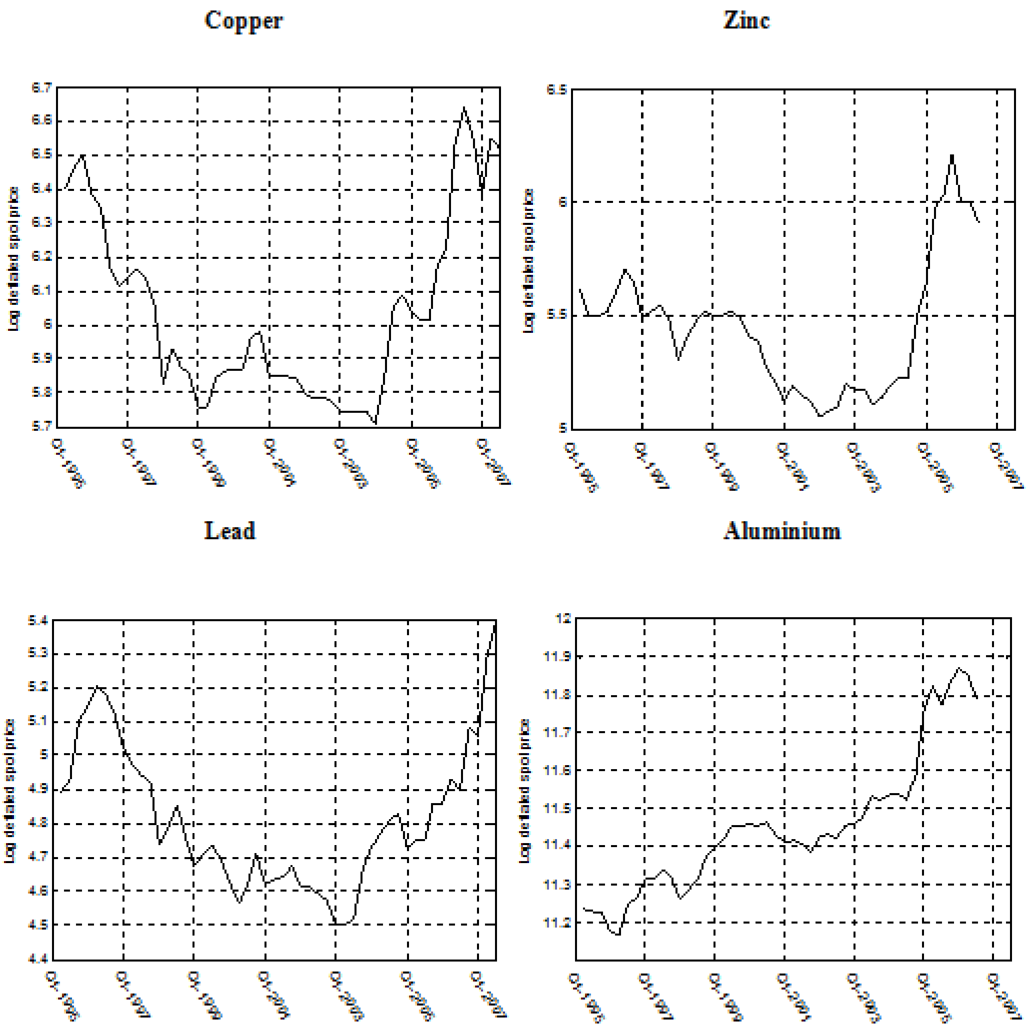

Figure 2: Logarithm of Average Quarterly Deflated Prices of Four Metals in the Indian Commodity Market

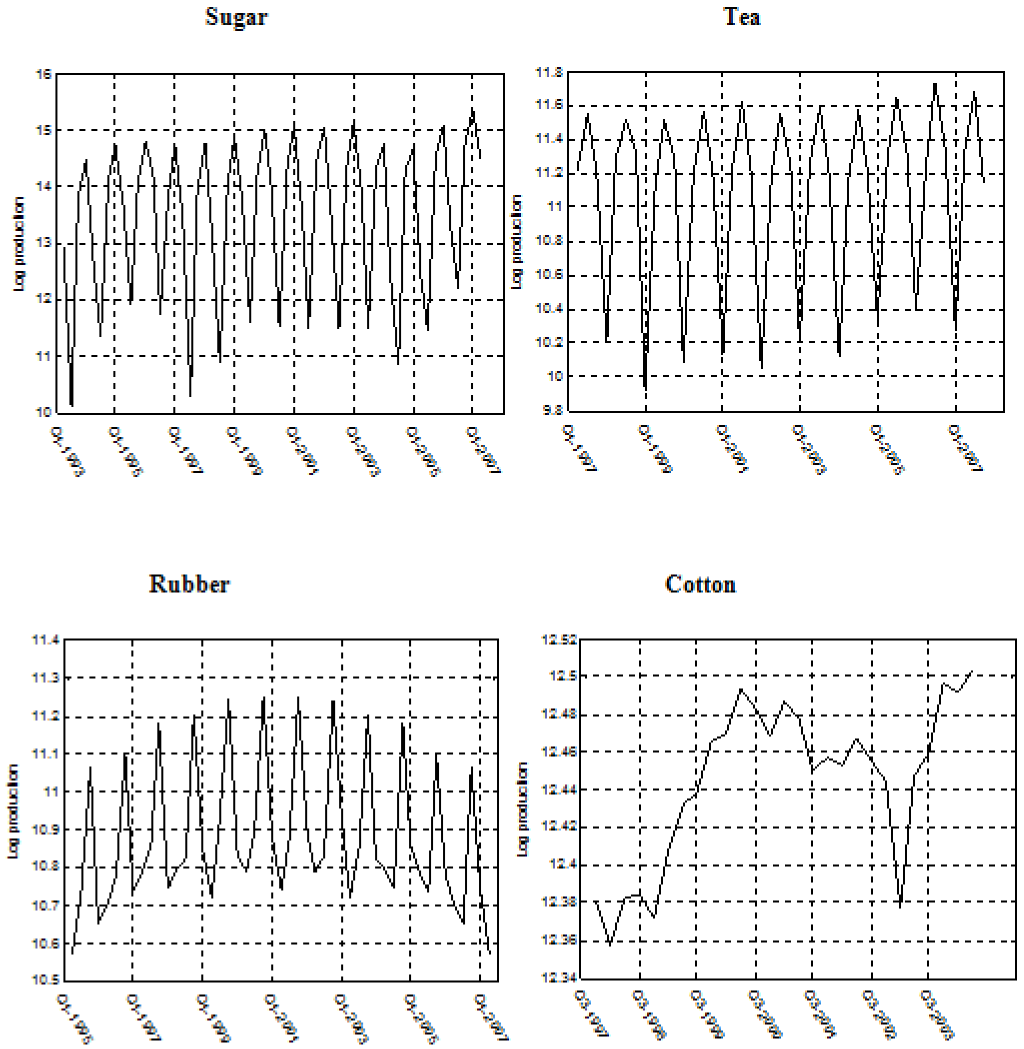

Figure 3: Logarithm of Average Quarterly Production of four Agricultural Commodities in the Indian Commodity Market

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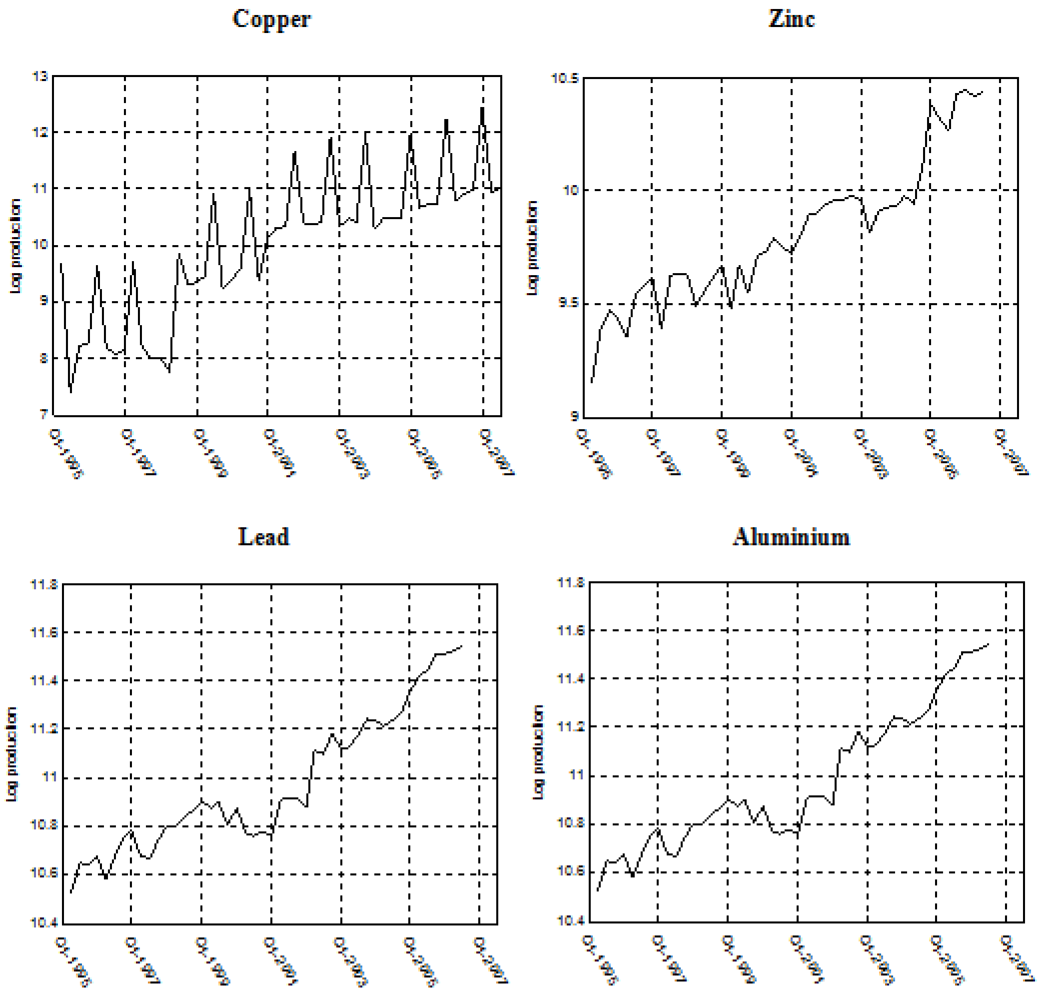

Figure 4: Logarithm of Average Quarterly Production of Four Metals in the Indian Commodity Market

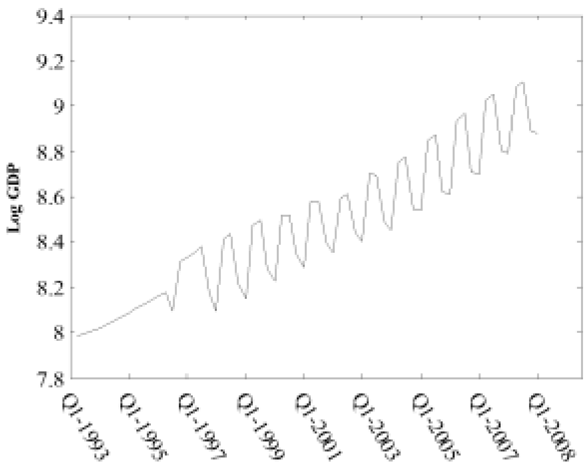

Figure 5: Logarithm of Average Quarterly GDP