Testing of the Seasonal Unit Root Hypothesis in the Price Indices of Agricultural Commodities in India

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ABSTRACT

The study analyzed the persistence of shocks to the seasonal time series of the price indices of selected agricultural commodities in India. The seasonal unit root test procedure proposed by Hylleberg et al. (1990) and Beaulieu and Miron (1992) were used for 10 major price indices of agricultural commodities. The study covered the period January 2000 to January 2013. Overall results provide significant and robust evidence rejecting the presence of unit roots at all seasonal frequencies for cereals; condiments and spices; eggs, meat, and fish; pulses; and vegetables. For the rest of the commodities studied, evidence indicates that the seasonality present is partly deterministic and partly stationary stochastic. These findings have important policy implications for policymakers and research analysts.

Keywords: seasonality, agricultural price indices, shocks, unit root tests, stationary
JEL Classification: C22, O13, Q11, Q17, Q18

INTRODUCTION

Many economic time series contain important seasonal components and there are a variety of models that consider seasonality (Hylleberg et al. 1990). Seasonality is known to be an empirical characteristic of many economic and financial series, including the commodity markets. It is especially important for agricultural commodities with seasonal production pattern (Jin et al. 2010). Because of their natural adherence to climate and pronounced seasonal cycles, prices of field crops constitute an interesting field for exploring seasonal time series models (Jumah and Kunst 2008).

A seasonal time series can be described as one with a spectrum having distinct peaks at the seasonal frequencies $w_s \equiv 2\pi j/s$, $j = 1, \ldots, s/2$, where s is the number of time periods in a year, assuming s to be an even number and that a spectrum exists (Hylleberg et al. 1990). Structural models of commodity markets usually assume that the random variables are stationary (Wang and Tomek 2004). However, empirical results have shown the existence of unit roots in the commodity prices in the presence or absence of seasonality.

Agricultural prices play a significant role in the overall price level and thus receive considerable concern of policymakers. Moreover, according to Tomek (1994) "an understanding of the time-series properties of agricultural product prices is a prerequisite to analyzing risk management and forecasting problems." Bickel (1975) notes that "historical price data of many agricultural products exhibit definite seasonal patterns, which reflect the various marketing practices of farmers as well as the natural biological processes that govern production." Agricultural commodity prices are generally lower during the harvesting season due to adequate supply and high during the end of the marketing season due to inadequate availability of the crop. This general pattern, a normal feature for food grains, is recurrent mainly due to the seasonality in supply and factors affecting hoarding by traders.

With this backdrop, the study sets the objective of testing unit roots in the context of seasonal time series of the price indices of selected agricultural commodities. In doing so, we used the seasonal unit root test procedure proposed by Hylleberg et al. (1990) as it has the advantage of appropriate transformations following directly from the procedure itself–they do not have to be implemented a priori. The economic rationale for applying the unit root test is quite significant. If agricultural prices are non-stationary (containing a unit root), it means that its mean or variance will change over time. From a policy point of view, the impact of a shock will be permanent in such case and the prices will not be able to adjust toward their long-run trend path, raising more uncertainty in agricultural prices. Moreover, a non-stationary process implies that the instability of agricultural prices increases over time, and any policy or marketing campaigns developed with the aim of stimulating the agricultural products would be misguided efforts, making it infeasible to carry out planning and promotion strategies. In other words, there is little that can be done to forecast the price. On the contrary, stationary agricultural prices imply that any policy aimed at influencing the prices of these commodities will not have a permanent mpact as the prices tend to revert to the mean. If government/policymakers wish to control food prices, they need to make policies that influence the prices of commodities exhibiting the unit root behavior. Moreover, in case of uncertainty (whether or not price shocks are persistent), producers may diversify commodity production, which hopefully would reduce the risks associated with the persistence of shocks and price unpredictability.

In our study, we applied the latest econometric technique on 10 major agricultural price indices. To the best of our knowledge, none such studies have included 10 major agricultural price indices in Indian context. Hence, any new study will contribute to the literature. In addition, our study has some practical implications on policy.

The rest of the paper is organized into the following sections: review of literature, seasonal properties of selected agricultural commodities, methodology, results and discussion, and conclusion.

A BRIEF REVIEW OF LITERATURE

Beaulieu and Miron (1992) provide evidence on the presence of seasonal unit roots in aggregate U.S. data using HEGY, the approach developed by Hylleberg et al. (1990). They first derived the mechanics and asymptotic of the HEGY procedure for monthly data and used Monte Carlo methods to compute the finite sample critical values of the associated test statistics. Quarterly and monthly HEGY procedures were then applied to aggregate data. The data rejected the presence of unit roots at most seasonal frequencies in a large fraction of the series considered.

Sharma and Zemcik (2004) introduce a sequential strategy of testing for seasonal unit roots. Their study further built on the Hylleberg et al. (1990) test by considering the uncertainty about the deterministic components. Specifically, it proposed a set of *F*-type statistics to jointly test seasonal unit roots and deterministic components in a quarterly series. The percentiles of the proposed statistics obtained by using the Monte Carlo methods were reported. The results showed that in two cases, seasonality was due to seasonal dummies and a seasonal trend. In the second step, HEGY tests were conducted. Results indicate that many of the series contained non-seasonal unit root; only three of them contained a seasonal one.

Wang and Tomek (2004) applied various specifications to Illinois farm prices of corn, soybeans, barrows and gilts, and milk for the period 1960–2002 to see if commodity prices were non-stationary. The preponderance of the evidence suggests that nominal prices did not have unit roots, but under certain specifications, the null hypothesis of a unit root could not be rejected, particularly when the logarithms of prices were used. If the test specification did not account for a structural change that shifted the mean of the variable, the results were biased toward the conclusion that a unit root existed. In general, the evidence did not favor the existence of unit roots. The results showed that the specification of the test equation often influenced the test outcome, which is a well-known phenomenon in hypothesis testing.

Smith, Taylor, and Castro (2007) provided regression-based test statistics for seasonal unit roots for a general seasonal aspect of the data, which were similar both exactly and asymptotically with respect to initial values of the time series process and seasonal drift parameters. They provided a general characterization result, which clarified precisely the null and alternative sub-hypotheses under test in the regression approach of Hylleberg et al. (1990). Asymptotic distribution theory coupled with a set of Monte Carlo experiments indicated that a t-statistic approach, as advocated by Hylleberg et al. (1990), to test for unit roots at the harmonic seasonal frequencies could not be recommended, and therefore the use of a joint F-test based approach was appropriate.

Ovararin and Meade (2010) investigated mean reversion and seasonality on three agricultural commodities (rough/paddy rice, rubber, and white sugar) using GARCH model. Findings show that seasonal patterns dominated in the volatility estimation: GARCH (1,1) with seasonality in mean equation and GARCH (1,1) with seasonality in mean equation and volatility. Therefore, seasonality is an important additional parameter, providing a more realistic volatility model for agricultural products.

Lehecka (2013) examined whether seasonality in agricultural commodity prices is deterministic, time-constant, and should be modeled using seasonal dummies or unit root stochastic. Results showed rejections of all seasonal unit roots and insignificant changes in seasonal patterns. Hence, seasonal variations in agricultural commodity prices should be modeled by seasonal dummies.

SEASONAL PROPERTIES OF SELECTED AGRICULTURAL COMMODITIES

This section examines the seasonal properties of the agricultural commodities used in the analysis (all related plots are presented in Appendix 2). Looking at the seasonal plot of cereal, we see that prices remained in the range of 4.6–5.3 percent during 2000–2012. During 2000–2002 and 2005, prices hovered around 4.6 percent, remaining stable until July. In 2000, prices started falling from July until October. In 2002, prices showed a rising trend around July, whereas in 2006, prices increased from August onwards after falling sharply after April 2006. It rose above 4.6 percent starting in November. In 2007, prices remained around 4.8 percent. They generally showed a rising trend from 4.9 to 5 percent, with fewer fluctuations in 2008. In 2009, prices showed increasing trend after August. During 2010–2012, prices were around 5.1 to 5.2 percent and remained around this level until June 2012, after which it rose beyond 5.3 percent. Thus, we conclude that prices of cereal tend to increase after July.

In the case of egg, meat, and fish, we observed that for the period 2000–2009, prices were in the range of 4.4–5 percent and hovered around 5.2 to 5.5 percent during 2010–2012. Further, monthly movements of prices show a fall in the price in 2001 (starting after July from 4.5% to 4.4%) by the end of the year. Moreover, price direction normally changed after April during 2001–2009.

The analysis of these food commodities revealed the existence of three price-period bands: 2001–2006, 2007–2009, and 2010–2012. Prices fluctuated between 4.5 and 4.7 percent in the first band (2001–2006), between 4.8 and 4.9 percent in the second band (2007–2009), and between 5.1 and 5.3 percent in the third band (2010–2012). Further, prices dipped quite significantly in March and April 2011. However, prices of the food commodities were less volatile.

Quite a significant variation was observed in case of prices of fruits and vegetables in all the years. In general, these commodities' prices ranged from 4.2 to 5.4 percent during 2000–2012. During 2002–2005, prices increased from 4.5 to 4.7 percent, but sharply fell in November. Turning points are more visible in 2001: prices increased from 4.3 to above 4.4 percent from January to April, remained stable from April to July, and steeply rose after July, reaching 4.6 percent in September. The fluctuation was different in 2011: prices fell in February, jumped in March, and fell again in November. During 2007–2008, prices started rising from 4.7 percent in January, reaching above 4.8 percent in August; thereafter, it started falling. In 2012, prices rose sharply in February through April, and started falling thereafter.

In the case of the other food articles (cereals, pulses, fruits and vegetables, milk, egg, meat and fish, and condiments and spices), more fluctuations were observed in all the years except 2012, when prices fell in March but remained around 5.5 percent in the other months. In 2000, prices were low in March to April but sharply increased thereafter, reaching 5 percent in June. After June, price started falling until November. A similar trend was seen in 2001, although fluctuations were not much prominent as in 2000. In 2002, prices suddenly jumped from 4.4 percent in March to 4.9 percent in June. Prices in 2003 increased from 4.8 to around 5.2 percent from January to September, and remained between 5.0 and 5.2 percent from September to December. However, prices had a sharp fall starting in January 2004 through April of that year. Prices remained stable all throughout 2005–2007 and 2010.

Prices of pulses remained between 4.6 and 4.7 percent during 2000–2005. They showed an increasing trend in 2006 and 2008–2009 and a declining trend in 2007. In 2010–2012, prices fell in February and March but increased after May.

Fluctuations in the prices of fruits were quite evident during the period 2000–2012, where the prices varied between 4.2 and 5.5 percent. In 2000, prices fell thrice in March, July, and October, with July showing the most price decline. In 2001, prices were stable at around 4.4 percent until May; they suddenly fell to 4.2 percent in July but jumped to 4.6 percent in September. Prices in 2002–2003 also declined sharply in July. They remained less volatile during the period 2005–2007 and 2009. Prices during 2010–2012 showed an almost similar trend—rising in April and declining thereafter.

Vegetable prices were highly volatile during 2000–2012. For instance, during 2000–2003 and 2005, prices were in the range of 4.2 to 4.4 percent in June and increased to the range of 4.4 to 4.8 percent in November; they dipped in May, September, and December. In 2006, prices were around 4.6 percent in January, fell to 4.4 percent in March to April, and increased thereafter, reaching 4.8 percent in October. During 2007–2010 and 2011, prices were around 5 percent in January to May and reached around 5.4 percernt in September to October. In 2012, prices increased sharply to 5.5 percent in April and declined starting in June.

As for condiments/spices, prices remained almost stable throughout 2000–2003. In 2006, prices steadily increased; a similar pattern was observed in 2009. Prices in 2011 fell in March, September, and December. Thus, we can conclude that the prices of condiments/spices were stable during the period under study.

Prices of milk during 2000–2012 were in the range of 4.4 to 5.4 percent. We observed that prices were normally low in January and February and high around June onwards. We can conclude that the prices of milk remained less volatile in 2000–2012.

DATA AND ESTIMATION METHODOLOGY

Several methods are proposed in the econometric literature for testing unit roots in the context of seasonal time series. These include methods developed by Hylleberg et al. (1990), Canova and Hansen (1995), Caner (1998), and Shin and So (2000). We used the seasonal unit root test procedure HEGY proposed by Hylleberg et al. (1990). Compared with other seasonal unit root tests (e.g., Dickey, Hasza, and Fuller 1984), the HEGY test has the advantage in that the appropriate transformations, in order to remove possible (seasonal) unit roots, follow directly from the procedure itself and do not have to be implemented a priori. Hylleberg et al. (1990) proposed a method to test whether a time series contains seasonal unit roots in the presence of other unit roots and seasonal processes. Applying $(1-L^4)$ to quarterly series, where L is the usual lag operator, implies that one assumes the presence of four unit roots, as $(1-L^4) = (1-L)(1+L)(1-iL)(1+iL) = (1-L)(1+L)(1+L^2)$, hence the unit roots are $1, -1, i,$ and $-i'$. Hylleberg et al. (1990) show that testing for seasonal unit roots amounts to testing the significance of the parameters of an auxiliary regression, which may also contain deterministic elements like a constant, trend, and seasonal dummies. The auxiliary regression derived is:

$$\Delta_4 y_t = \pi_1 z_{1,t-1} + \pi_2 z_{2,t-1} + \pi_3 z_{3,t-1} + \pi_4 z_{3,t-2} + \sum_{j=1}^{p} \alpha_j^* \Delta_4 y_{t-j} + \varepsilon_t \quad (1)$$

where y_t is the time being tested, $z_{1t} = (1+L+L^2+L^3)y_t$, $z_{2t} = (-1+L-L^2+L^3)y_t$, $z_{3t} = (-1+L^2)y_t$, and $z_{4t} = (1-L^4)y_t = \Delta_4 y_t = y_t - y_{t-4}$, L denoting the usual lag operator, and where $\{\varepsilon_t\}$ is assumed to be a white noise process.

Applying OLS to this auxiliary regression gives estimates of the π_i's. Using the HEGY test, when $\pi_1 = 0$ the series contains the (non-seasonal or zero frequency) root 1, when $\pi_2 = 0$ the (semi-annual) root -1 is present, i.e., root -1 corresponds to unit roots ½ cycle per quarter or 2 cycles per year, the presence of the (annual) *roots* $\pm i$ $(i = \sqrt{-1})$, implying $\pi_3 = \pi_4 = 0$ (the stationary alternatives being $\pi_1 < 0$, $\pi_2 < 0$, and $\pi_3 < 0$ and/or $\pi_4 = 0$), i.e., $\pm i$ corresponds to unit roots at ¼ cycle per quarter or one cycle per year.

Thus, inference on the presence of seasonal unit roots may be carried out through the t-ratios associated with the last three π_i coefficients: $t\pi_2$, $t\pi_3$, and $t\pi_4$. On the other hand, evidence on the presence or absence of a non-seasonal unit root is given by $t\pi_1$. The analysis of stochastic seasonal non-stationarity becomes simpler if, instead of testing three separate hypotheses, we test some joint null hypotheses. To that end, one can use the F-statistics F_{34}, which tests $H_0: \pi_3 = \pi_4 = 0$, and F_{234}, associated with $H_0: \pi_2 = \pi_3 = \pi_4 = 0$. Finally, one can also test whether all the πi parameters are zero (i.e., whether the $\Delta_4 = (1 - L^4)$ filter is appropriate) using F_{1234}. The asymptotic distributions of the test statistics under the respective null hypotheses depend on the deterministic terms in the model.

The number of lagged seasonal differences $\Delta_4 y_{t-j}$ has to be chosen before the HEGY tests can be performed. This may again be done by using model selection criteria or parameter significance tests.

As for quarterly series, the test for monthly time series also amount to testing the significance in an auxiliary regression. In monthly series the $(1-L^{12})$ filter has 12 unit roots. We then have:

$$1-L^{12} = (1-L)(1+L)(1-iL)(1+iL)(1+\frac{\sqrt{3}+i}{2}L)(1+\frac{\sqrt{3}-i}{2})(1-\frac{\sqrt{3}+i}{2}L)(1-\frac{\sqrt{3}-i}{2}L)(1+\frac{i\sqrt{3}+1}{2}L)(1-\frac{i\sqrt{3}+1}{2}L)(1-\frac{i\sqrt{3}+1}{2}L)(1+\frac{i\sqrt{3}-1}{2}L) \quad (2)$$

Collecting two terms at a time, we can write this equation as

$$(1-L^{12}) = (1-L^2)(1+L^2)(1+\sqrt{3}L+L^2)(1-\sqrt{3}L+L^2)(1+L+L^2)(1+L+L^2) = (1-L^4)(1-L^2+L^4)(1+L^2+L^4).$$

For monthly series, Franses (1990) discussed the corresponding tests for seasonal unit roots based on the model:

$$\Delta_{12} y_t = \pi_1 z_{1,t-1} + \pi_2 z_{2,t-1} + \pi_3 z_{3,t-1} + \pi_4 z_{3,t-2} + \pi_5 z_{4,t-1} + \pi_6 z_{4,t-2} + \pi_7 z_{5,t-1} + \pi_8 z_{5,t-2} + \pi_9 z_{6,t-1} + \pi_{10} z_{6,t-2} + \pi_{11} z_{7,t-1} + \pi_{12} z_{7,t-2} + \sum_{j=1}^{p} a_j^* \Delta_{12} y_{t-j} + \varepsilon_t \quad (3)$$

where:

$z_{1,t} = (1+L)(1+L^2)(1+L^4+L^8)y_t$

$z_{2,t} = -(1-L)(1+L^2)(1+L^4+L^8)y_t$

$z_{3,t} = -(1-L^2)(1+L^4+L^8)y_t$

$z_{4,t} = -(1-L^4)(1-\sqrt{3}L+L^2)(1+L^4+L^8)y_t$

$z_{5,t} = -(1-L^4)(1+\sqrt{3}L+L^2)(1+L^4+L^8)y_t$

$z_{6,t} = -(1-L^4)(1-L^2+L^4)(1-L+L^2)y_t$

$z_{7,t} = -(1-L^4)(1-L^2+L^4)(1+L+L^2)y_t$

$z_{8,t} = (1-L^{12})y_t$

The process y_t has a regular (zero frequency) unit root if $\pi_t = 0$; it has seasonal unit roots if any one of the other $\pi_i (i = 2,...,12)$ is zero. For the conjugate complex roots, $\pi_i = \pi_i +_1 = 0$ $(i= 3, 5, 7, 9, 11)$ is required. The corresponding statistical hypotheses can again be checked by t- and F-statistics, critical values for which are given by Franses and Hobijn (1997). If all the $\pi_i (i = 2,...,12)$ are zero, then a stationary model for the monthly seasonal differences of the series is suitable.[1] As in the case of quarterly series it is also possible to include deterministic terms in model (2).

Beaulieu and Miron (1992) used the HEGY approach in a slightly different way to derive the mechanics of another procedure to test for seasonal unit roots using monthly data. They derived the asymptotic of the HEGY procedure for monthly data and used Monte Carlo methods to compute the finite sample critical values of the associated test statistics. The main difference Beaulieu and Miron's (1992) methodology compared with Franses' (1991a;1991b) is that the former used mutually orthogonal regressors, obtaining a different, somewhat more complicated test equation.

Suppose that the series of interest (X_t) is generated by a general process like:

$$\varphi(L)X_t = \alpha_0 + \alpha_1 t + \sum_{k=2}^{12} \alpha_k D_{kt} + \varepsilon_t \qquad (4)$$

where ε_t is a white noise process and the deterministic terms include a constant, a linear trend, and seasonal dummies. "We wish to know whether the polynomial in the backshift operator, $\varphi(L)$, has roots equal to one in absolute value at the zero or seasonal frequencies. In particular, the goal is to test hypotheses about a particular unit root without taking a stand on whether other seasonal or zero frequency unit roots are present" (Beaulieu and Miron 1992).

The auxiliary regression model that allows the performance of the test is given by the following equation:

$$\varphi(L)^* Y13_t = \alpha_0 + \alpha_1 t + \sum_{k=2}^{12} \alpha_k D_{kt} + \sum_{k=1}^{12} \pi_k Yk_{t-1} + \varepsilon_t \qquad (5)$$

where $Yk_t (k = 1, 2,...,13)$ are auxiliary variables obtained by appropriately filtering the variable under study (X_t). The $\varphi(L)^*$ polynomial is a remainder with roots outside the unit circle that allows the augmentation necessary to whiten the errors in the estimation of the above equation. In order to test hypotheses about various unit roots, one estimates (the test equation) by Ordinary Least Squares (OLS) and then compares the OLS statistics to the appropriate finite sample distributions based on Monte Carlo results (Beaulieu and Miron 1992). The inclusion or not of a trend in the deterministic part of model (5) depends on the hypothesized alternative to the null hypothesis of 12 unit roots.

Hence, there are 12 possible unit roots: one non-seasonal and 11 seasonal. Out of the 11 seasonal unit roots, one is real and the other 10 form five pairs of complex conjugates. Beaulieu and Miron (1992) provided the asymptotic distribution of the statistics necessary to

1 A detailed table of null hypotheses, alternative hypotheses, and test statistic used is presented in Appendix Table 1a.

perform the tests: t_1, t_2, t_3 and t_{k+1}, where $k \in \{3,5,7,9,11\}$. They also proved that the asymptotic distributions of the five t_k statistics are the same as those of the five t_{k+1}.

For ease of notation, Beaulieu and Miron (1992) indicated that k is 'odd' if $k \neq 1$ and $k \in \{3,5,7,9,11\}$ and that k is 'even' if $k \neq 2$ and $k \in \{4,6,8,10,12\}$. They showed that all the 'odd' statistics have the same distribution when different deterministic regressors are included in the regression. The same result was shown to be true in case of the 'even' statistics. The distributions of $t_2,...,t_{12}$ are independent of constant and trend terms. These terms only affect the distribution of t_1. Also, the distribution of t_2 when dummies are included in the regression is the same as that of t_1 when only a constant is included. The finite sample distributions obtained by Monte Carlo methods displayed all the characteristics of the asymptotic distributions mentioned in this paragraph.

We applied OLS to the auxiliary regression (5) in order to obtain the estimates of π_i and the corresponding standard errors. If all the estimated coefficients in this test regression are statistically different from zero, the series presents a stationary seasonal pattern and the correct procedure to model the series would be using seasonal dummies. In the case of $\pi_i = 0$, for $i = 1,...,12$, the series is seasonally integrated and it is appropriate to use the seasonal difference filter $(1-L^{12})$.

If $\pi_1 = 0$, then the presence of root $+1$ (zero frequency) cannot be rejected. There will be no seasonal unit roots if π_2 through π_{12} are significantly different from zero. When only some pairs of π's are equal to zero, one should consider using the corresponding implied operators. Abraham and Box (1978) showed how this kind of operators may sometimes be enough.

DATA ANALYSIS AND FINDINGS

Table 1 presents the results of the unit root analysis using HEGY test.[2] It shows the unit root results of price series of selected agricultural commodities. Critical values are reported in Appendix 1. The presence of a unit root at a particular frequency is established if the relevant test statistic is less than the corresponding tabulated critical value given in Franses and Hobijn (1997). It is evident from Table 1 that for all price series of the selected agricultural commodities, the null hypothesis of unit root at annual and semi-annual frequencies is accepted at 5 percent level of significance. However, based on the F-value, on the other hand, the null hypothesis of unit root at quarterly and all other higher frequencies is rejected at 5 percent level of significance for most of the price series of selected agricultural commodities.

These results suggest that agricultural price series are non-stationary at annual and quarterly level but not at the monthly or higher frequency level. That is, lower frequency data (e.g., annual or quarterly) will have higher fluctuations, particularly for agricultural commodities, than higher frequency data (e.g., monthly or weekly). Higher fluctuation leads to more variation and wider standard deviation around the mean, which leads to non-stationary at level. But in the case of daily or weekly data (agricultural commodities do not fluctuate like stock price or exchange rate), volatility will be less and around the mean, which might be the factor for stationary at level for high frequency data.

We then tested the robustness of our results using the Beaulieu and Miron (1992) test.

2 Critical values of the HEGY test for all cases are presented in Appendix 1.

Table 1. Test statistics under HEGY unit root test: Intercept, seasonal dummies, and trend (Franses and B. Hobijn 1997)

	Lags	$t(\pi_1)$	$t(\pi_2)$	$F(\pi_3, \pi_4)$	$F(\pi_5, \pi_6)$	$F(\pi_7, \pi_8)$	$F(\pi_9, \pi_{10})$	$F(\pi_{11}, \pi_{12})$	$F(\pi_2 \ldots\ldots \pi_{12})$	$F(\pi_1 \ldots\ldots \pi_{12})$
Cereals	0	1.3102	1.2291	7.198*	25.834*	13.879*	13.6702*	14.0097*	137.1372*	146.2853*
Condi-ments & spices	0	2.5905	2.6749	15.506*	10.253*	9.774*	18.6863*	15.6896*	380.6083*	401.4351*
Eggs, meat, & fish	0	0.3716	0.5167	15.46*	12.281*	11.217*	15.5758*	7.4374*	103.5887*	112.523*
Food articles	0	1.3698	1.1962	4.9067	24.321*	15.144*	8.7571*	6.8165*	86.2577*	93.8509*
Fruits	2	1.6894	1.6807	3.7144	13.23*	5.6192	4.1304	4.0776	8.1281*	8.2985*
Fruits & vege-tables	0	1.6661	1.5818	6.9437*	19.766*	7.2943*	10.2105*	4.356	34.1027*	37.1533*
Milk	0	1.4262	1.3118	9.9203*	22.111*	14.092*	13.6279*	8.9313*	173.1017*	188.6917*
Other food articles	3	2.7689	2.5441	25.352*	10.451*	8.5151*	18.7399*	18.5131*	23.0436*	22.4943*
Pulses	13	2.0621	2.1888	14.522*	6.752*	11.729*	6.87*	7.4263*	12.2289*	11.8592*
Vege-tables	2	4.0262	3.9655	4.4398	13.299*	8.3519*	14.5552*	5.9485	15.197*	13.8849*

Source: Authors' compilation

Note: * represents 5% level of significance

The results are reported in Table 2. The Beaulieu and Miron (1992) test allowed us to check for the integration of the series in its seasonal and non-seasonal parts, under the null hypotheses that the series is seasonally integrated of order one, i.e., SI (1,1). The null about the presence of a unit root at zero frequency was tested with the "t" statistic of the hypothesis $H_0 : \pi_1 = 0$ (called t_1 by Beaulieu and Miron 1992). The null hypotheses about the existence of seasonal unit roots were tested in each frequency by means of the "t" statistic associated with $H_0 : \pi_i = 0,$ for $i = 2, 3, ...,12,$ and/or by means of the *"F"* statistics corresponding to the joint hypotheses $H_0 : \pi_i = \pi_{i+1} = 0, for\ i = \{3, 5, 7, 9, 11\},$ which took into account all pairs of conjugate complex roots.[3] The significance tests for π_1 and π_2 are one-sided as well as those corresponding to π_i for 'even' *i*. On the contrary, those corresponding to 'odd' values of *i* should be two-sided.

The null hypothesis of the presence of unit roots at all seasonal frequencies was rejected for cereals; condiments and spices; eggs, meat, and fish; pulses; and vegetables. The null hypothesis was not rejected at π_{10}, π_{11}, F_{11-12} for Bajra (pearl millet); F_{5-6} for banana, cashew nut, food articles (cereals, pulses, fruits and vegetables, milk,

3 Franses (1991a) also obtained an F-statistic to test the joint hypothesis , for the presence of unit roots in all the seasonal frequencies.

Table 2. Beaulieu and Miron (1992) test

Frequency		*0*	*Pi*	*pi/2*	*2pi/3*	*pi/3*	*5pi/6*	*pi/6*	*pi/2*	*2pi/3*	*pi/3*	*5pi/6*	*pi/6*	*pi/2*	*2pi/3*	*pi/3*	*5pi/6*	*pi/6*
Roots	Lag	PI1	PI2	PI3	PI4	PI5	PI6	PI7	PI8	PI9	PI10	PI11	PI12	F[3-4]	F[5-6]	F[7-8]	F[9-10]	F[11-12]
Cereals	0	-4.43*	-2.00*	-1.89*	-3.90*	-4.63*	1.20*	-2.36*	-5.62*	-5.55*	3.35*	-2.30*	-4.93*	9.87*	11.74*	20.21*	24.53*	13.88*
Condiments & spices	0	-4.94*	-2.77*	-1.52*	-5.56*	-2.82*	5.01*	-2.48*	-5.63*	-4.05*	1.56*	-1.46*	-4.33*	17.32*	18.50*	20.75*	9.78*	9.77*
Eggs, meat, & fish	0	-3.31*	-3.10*	-4.07*	-4.28*	-2.74*	4.45*	-2.08*	-4.09*	-4.33*	1.81*	-1.88*	-4.56*	19.89*	15.05*	11.16*	11.46*	11.22*
Food articles	0	-4.49*	-3.29*	-3.41*	-2.84*	-2.29*	2.51*	-1.92*	-4.60*	-5.43*	3.28*	-3.07*	-4.69*	10.71*	6.1	12.98*	22.90*	15.14*
Fruits	2	-3.00*	-3.81*	-1.81*	-2.92*	-2.10*	1.24*	-1.48*	-3.41*	-4.38*	2.43	-1.87	-3.07*	6.05*	2.98	6.83*	12.48*	5.62
Fruits & vegetables	0	-2.11*	-4.56*	-5.06*	-1.67*	-2.06*	2.76*	-1.37*	-3.79*	-5.51*	1.88	-3.35*	-2.21*	14.82*	6.26*	8.29*	18.07*	7.29*
Milk	0	-5.42*	-2.80*	-3.44*	-3.86*	-2.85*	3.93*	-3.27*	-3.71*	-6.30*	1.00*	-1.79*	-5.25*	14.90*	12.98*	13.31*	19.97*	14.09*
Other food articles	3	-4.39*	-2.55*	-4.03*	-6.33*	-5.63*	1.80*	-3.74*	-5.14*	-4.43*	0.48	-0.59*	-4.09*	28.70*	18.18*	22.04*	9.83*	8.52*
Pulses	13	-5.33*	-1.77*	-0.50*	-5.74*	-3.17*	1.60*	-2.43*	-4.28*	-2.85*	2.00*	-1.89*	-4.77*	16.54*	6.25*	12.18*	6.45*	11.73*
Vegetables	2	-2.95*	-3.25*	-3.67*	-2.86*	-2.53*	3.85*	-2.47*	-5.07*	-3.90*	1.59*	-3.54*	-2.90*	11.43*	10.64*	15.21*	8.50*	9.47*

Source: Authors' compilation

Note: *represents 5% level of significance egg, meat and fish, and condiments and spices), and onion; F_{7-8} for betelnut/arecanut; F_{9-10} for chilies (dry), inland fish, and maize; π_{10} for coconut (fresh), coriander, fruits and vegetables, garlic, okra (lady finger), other food articles (cereals, pulses, fruits and vegetables, milk, egg, meat and fish, condiments and spices), and Ragi; $\pi_2 - \pi_7$, $\pi_{10} - \pi_{12}$, F_{2-4}, F_{5-6}, F_{9-10}, F_{11-12} for coffee; $\pi_{10} - \pi_{11}$, F_{5-6}, F_{11-12} for fruits; $\pi_{10} - \pi_{11}$, F_{11-12} for pineapple; F_{5-6}, F_{9-10} for potato; $\pi_9 - \pi_{11}$, F_{5-6}, F_{9-10}, F_{11-12} for sweet potato; and $\pi_1 - \pi_7$, $\pi_9 - \pi_{11}$, F_{5-6}, F_{9-10}, F_{11-12} for wheat. These results imply that the seasonality present in the monthly series for these commodities is partly deterministic and partly stationary stochastic. As a consequence, the first difference of this series may be modeled with seasonal dummies to take seasonality into account.

CONCLUSION

The study tested whether shocks to the seasonal time series of the price indices of selected agricultural commodities are temporary or permanent. It covered the period January 2000 to January 2013. The estimation was carried out using the seasonal unit root test procedure HEGY proposed by Hylleberg et al. (1990); robustness was analysed by relying on the results obtained from the Beaulieu and Miron (1992) test.

Results using the HEGY test show that for all price indices of the selected agricultural commodities, the null hypothesis of unit root at annual and semi-annual frequencies were accepted at 5 percent level of significance. However, based on the F-value, the null hypothesis of unit root at quarterly and all other higher frequencies were rejected at 5 percent level of significance for most of the price series of selected agricultural commodities. Further, results from the Beaulieu and Miron (1992) test indicate the rejection of the null hypothesis of the presence of unit roots at all seasonal frequencies for cereals; condiments and spices; eggs, meat, and fish; pulses; and vegetables. For the rest of the commodities, the seasonality present in these monthly series is partly deterministic and partly stationary stochastic.

From a policy perspective, results of this study imply that forecasting of prices of cereals; condiments and spices; eggs, meat, and fish; pulses; and vegetables would give reliable results. Moreover, any policy attempt or even a seasonal shock to affect the prices of these commodities will have only a temporary effect. On the other hand, for commodities where existence of seasonality is partly deterministic and partly stationary stochastic, one may use the first difference of such series with seasonal dummies to take seasonality into account for forecasting purpose. In this case, a policy attempt or seasonal shocks on the prices of such commodities would be long-lasting.

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APPENDIX 1

Table 1A: Tests of seasonal unit root in monthly data

Null Hypothesis	Alternative Hypothesis	Test Statistic
$\pi_1 = 0$	$\pi_1 < 0$	$t(\pi_1)$
$\pi_2 = 0$	$\pi_2 < 0$	$t(\pi_2)$
$\pi_3 \cap \pi_4 = 0$	$\pi_3 \cup \pi_4 \neq 0$	$F(\pi_3, \pi_4)$
$\pi_5 \cap \pi_6 = 0$	$\pi_5 \cup \pi_6 \neq 0$	$F(\pi_5, \pi_6)$
$\pi_7 \cap \pi_8 = 0$	$\pi_7 \quad \pi_8 \neq 0$	$F(\pi_7, \pi_8)$
$\pi_9 \cap \pi_{10} = 0$	$\pi_9 \cup \pi_{10} \neq 0$	$F(\pi_9, \pi_{10})$
$\pi_{11} \cap \pi_{12} = 0$	$\pi_{11} \cup \pi_{12} \neq 0$	$F(\pi_{11}, \pi_{12})$
$\pi_2 \cap \ldots\ldots \cap \pi_{12} = 0$	$\pi_2 \cup \ldots. \cup \pi_4 \neq 0$	$F(\pi_2 \ldots\ldots \pi_{12})$
$\pi_1 \cap \ldots\ldots \cap \pi_{12} = 0$	$\pi_1 \cup \ldots. \cup \pi_4 \neq 0$	$F(\pi_1 \ldots\ldots \pi_{12})$

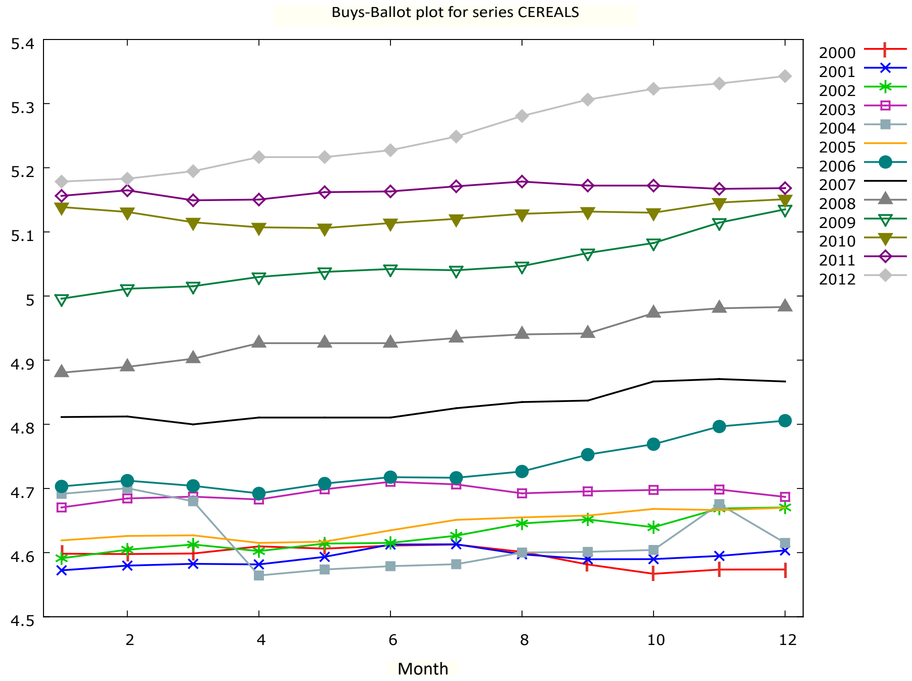
Table 2A: Critical values for the HEGY test

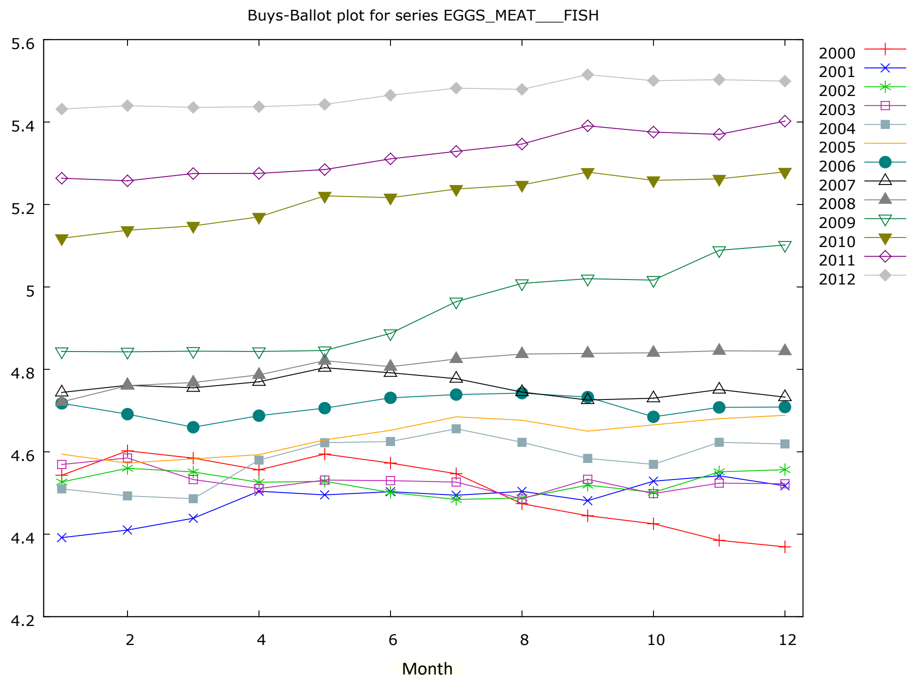
Test Statistic	$t(\pi_1)$	$t(\pi_2)$	$F(\pi_3, \pi_4)$	$F(\pi_5, \pi_6)$	$F(\pi_7, \pi_8)$	$F(\pi_9, \pi_{10})$	$F(\pi_{11}, \pi_{12})$	$F(\pi_{2\ldots} \pi_{12})$	$F(\pi_{1\ldots} \pi_{12})$
1%	-3.4	-3.34	8.4	8.58	8.39	8.56	8.76	5.05	5.17
5%	-2.81	-2.81	6.35	6.48	6.33	6.41	6.47	4.37	4.44
10%	-3.51	-2.51	5.45	5.46	5.32	5.46	5.36	4.04	4.08

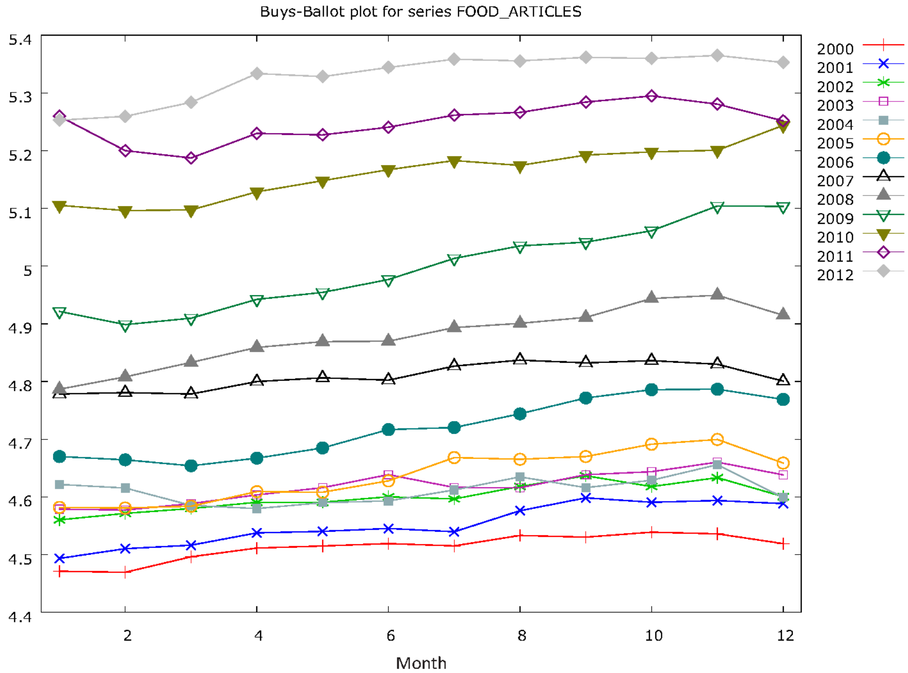
Note: Critical values were obtained from P.H. Franses and B. Hobijn (1997)

APPENDIX 2

SEASONALITY PLOTS



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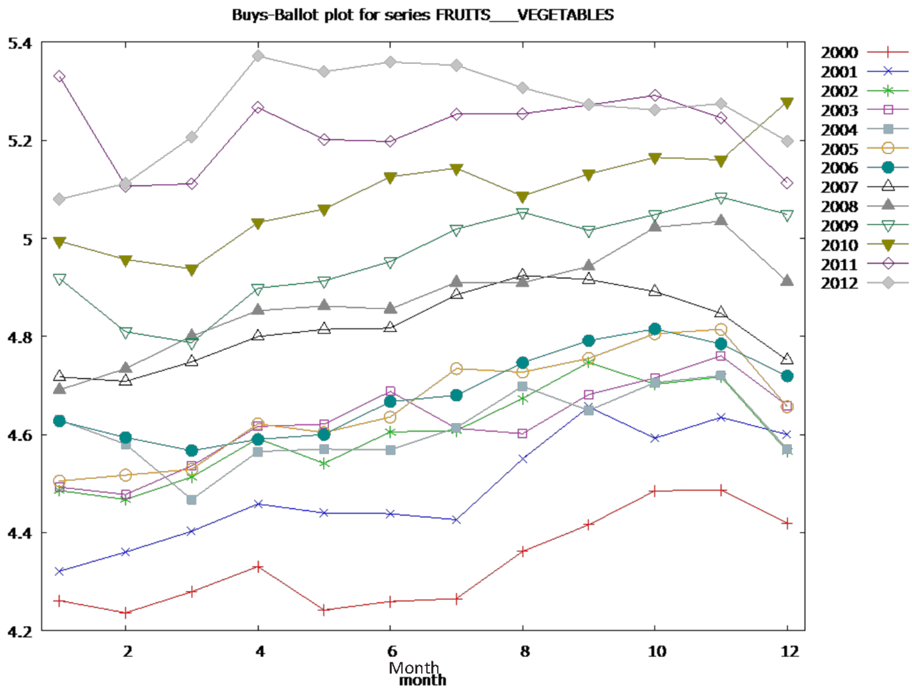
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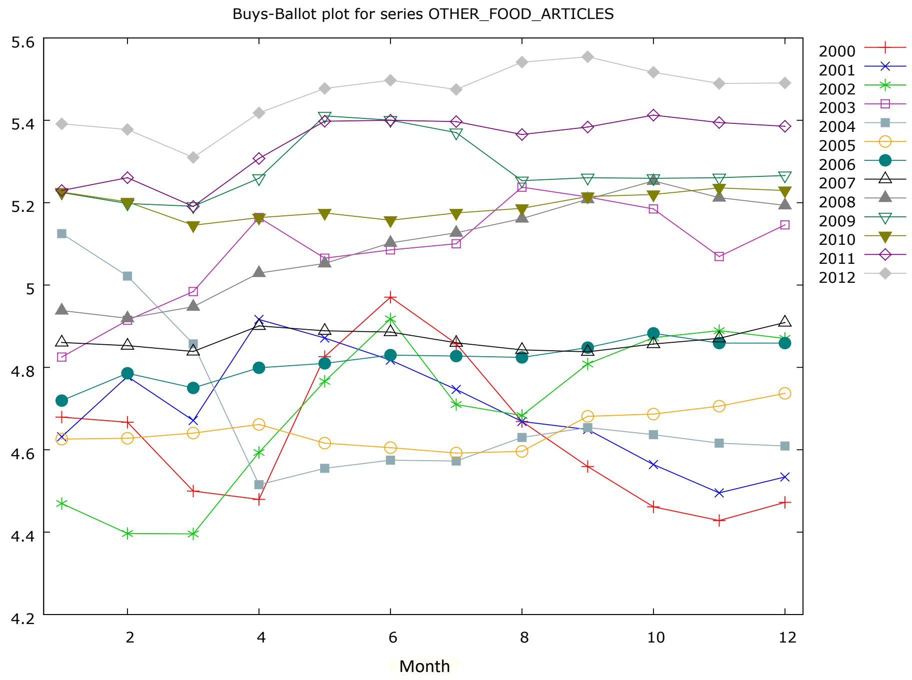
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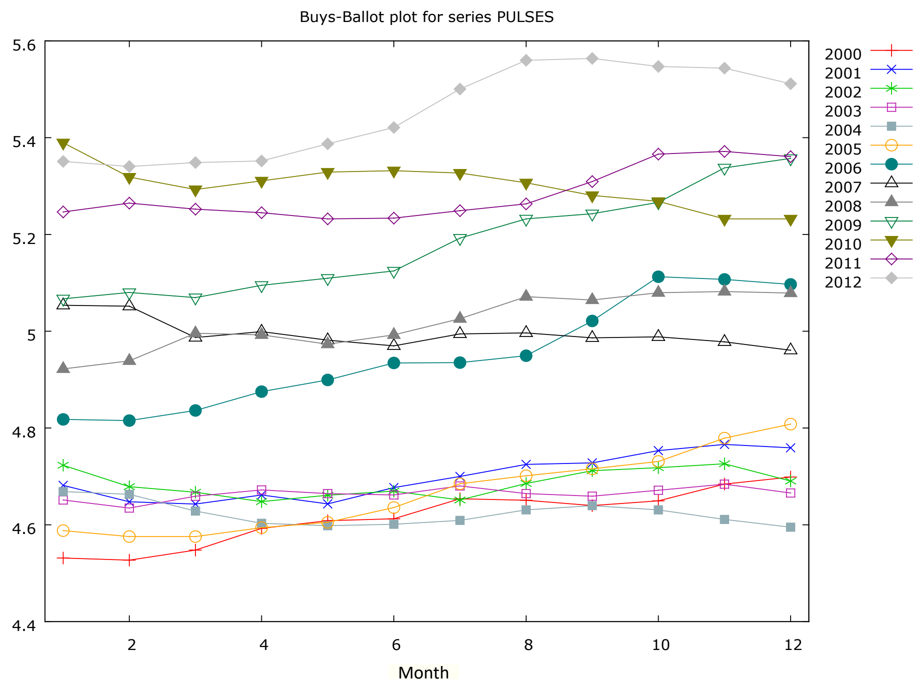
Buys-Ballot plot for series PULSES
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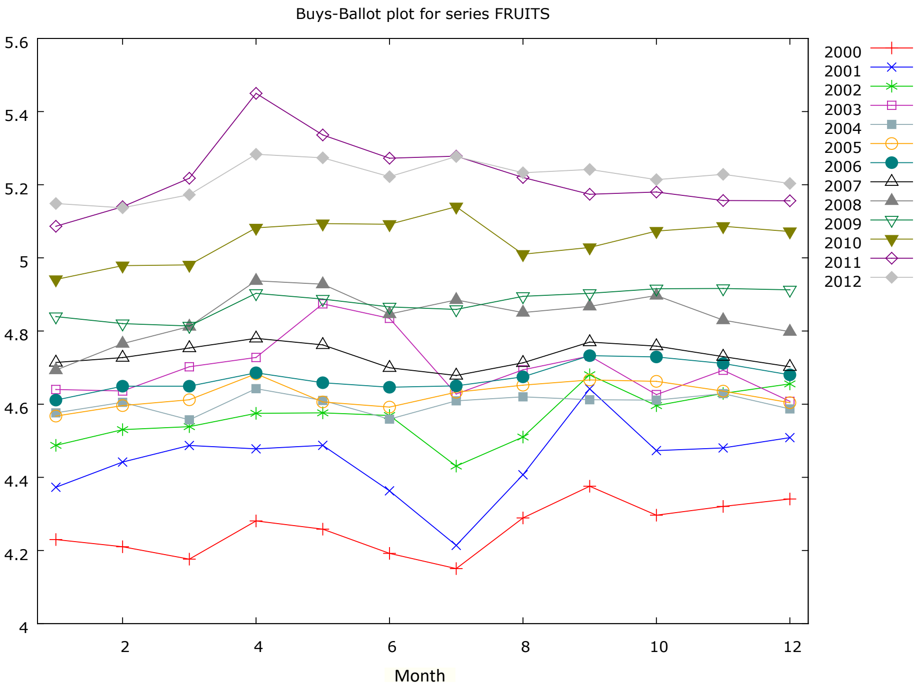
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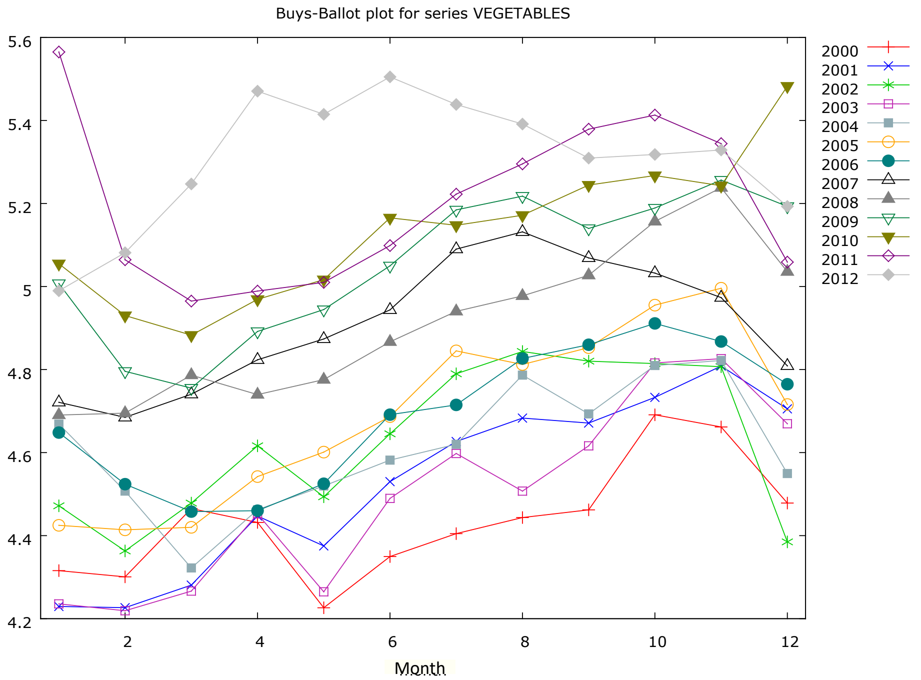
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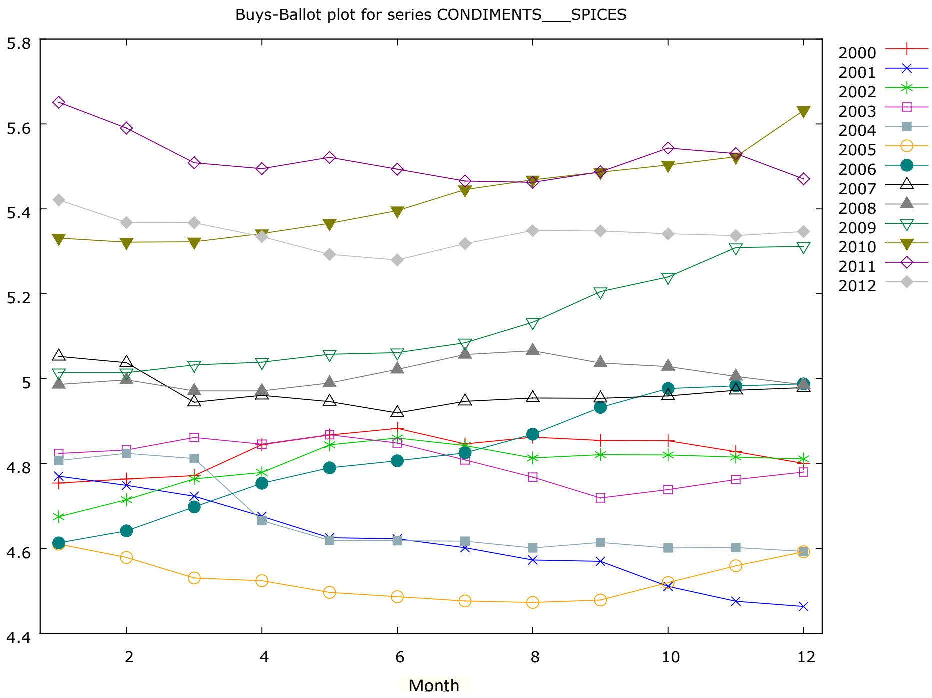
Buys-Ballot plot for series CONDIMENTS___SPICES
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4.8
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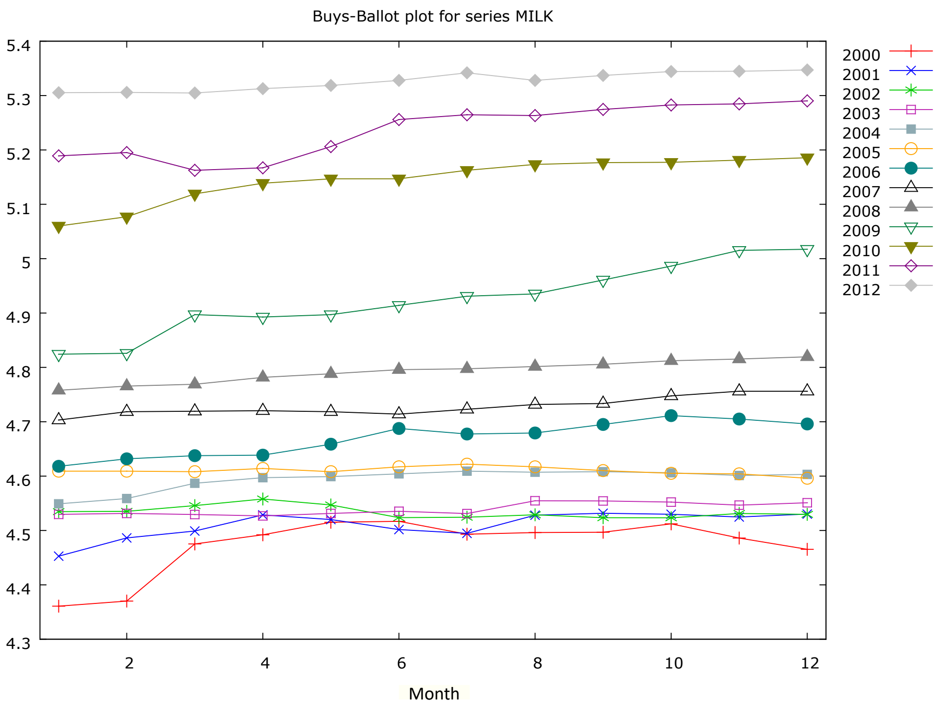
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