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Are daily agricultural grains prices stationary? New evidence from GARCH-based unit root tests

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Abstract

In this paper, we employ the GARCH-based unit root tests including the one proposed by Narayan and Liu (NL) (2015) to further examine the stationarity of daily agricultural grain prices from 1986 to 2015. We also compare the performance of these tests with standard unit root tests. Our results suggest that the unit root test for agricultural grains prices is better modeled in the presence of GARCH process with a time trend and possibly one or two shifts in the intercept. The policy implications of these findings are well documented in the paper.

Key Words: Trend, Structural break, Conditional heteroscedasticity, Unit root, Agricultural grains prices

JEL Classification: C12, C58, Q11

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1.0 Introduction

The need for unit root testing when modelling and forecasting with time series has been well documented in both the theoretical and empirical literature. Among the conventional unit root tests include the Augmented Dickey Fuller (ADF), Phillip-Perron (PP), Ng-Perron, and the Dickey-Fuller GLS unit root tests. However, there have been increasing evidence suggesting that the non-rejection of the unit root null hypothesis, which is often the case when the conventional unit root tests are used, may be due to the presence of structural breaks. Therefore, it has become a standard practice in time series modelling to account for structural breaks when testing for unit root. Examples of the unit root tests that account for structural breaks include the Perron (1989, 1997), Zivot and Andrews (1992), Strazicich et al. (2004), and Narayan and Popp (2010).

In recent times, a new dimension to unit root testing is gradually emerging. Empirically validated by Cook (2008) and extended by Narayan and Liu [NL] (2011, 2013, 2015), this new framework for unit root testing accounts for heteroscedasticity among other statistical features. This class of unit root test is termed “GARCH-based unit root tests”. Essentially, Cook (2008) developed a test for unit root in the presence of GARCH error and the test is found to have better and size power properties if there is evidence of significant conditional heteroscedasticity which is a prominent feature of high frequency time series data like daily frequency. However, one of the limitations of the Cook (2008) GARCH-based unit root test is that it does not account for structural breaks and therefore statistical inferences may be invalid if there is evidence of significant structural breaks. In response to this limitation, NL (2011, 2013) extended the GARCH-based unit root test to include two exogenous and endogenous structural breaks respectively and the application of this test is increasingly gaining prominence in the literature (see Salisu and Fasanya, 2013; Salisu and Mobolaji, 2013 and Mishra and Smyth, 2014a, b).

Recently, NL (2015) extended the NL (2011, 2013) test to include a time trend and two endogenous structural breaks and demonstrated that its exclusion in the test regression can be costly and can in fact be a source of power to reject the unit root null hypothesis. In other words, the test allows for a trend term in the test regression in addition to the two structural breaks and GARCH process as in NL (2011, 2013). In this paper, we extend the application of the GARCH-based unit root tests to agricultural grains prices namely Corn, Oats, Rice, Soybean and Wheat prices.[1] Testing the stationarity properties of agricultural grains prices will aid in drawing meaningful inference and possible policy implications. If an agricultural commodity price is non-stationary, the unit root will be transmitted to other macroeconomic variables. Thus, if there is a shock to the agricultural commodity market, given its importance to other sectors of the economy, other key macroeconomic variables may absorb that non-stationarity. Furthermore, when an agricultural commodity price exhibits stationarity, it is possible to forecast future movements in the series using its past behaviour. Therefore, a good understanding of the stationarity properties of agricultural grains prices is essential for policy design and forecast.

We use daily futures prices of these commodities that are expected to exhibit significant time trend, conditional heteroscedaticity as well as structural breaks. Interestingly, a number of studies modelling with agricultural commodities including agricultural grains have reported most of the series to be non-stationary using the standard unit root tests such as ADF and PP. Recent examples include Wang et al. (2014), Śmiech et al. (2015) and Zhang and Qu (2015).

[1] These tests have also been used by Salisu and Adeleke (2016) and Salisu et al. (2016) to test for unit roots in sovereign bold yield and stock returns respectively.

Foreshadowing our results, we find that the unit root test for the selected agricultural commodities is better modeled in the presence of a GARCH process with time trend and structural breaks. We structure the rest of the paper as follows. The next section explains the framework for the test. Section 3 presents graphs and preliminary analyses. The results of the unit root tests including robustness checks are discussed in Section 4 while Section 5 provides relevant policy implications. Section 6 however concludes the paper.

2.0 The GARCH-based unit root test

As earlier noted, a more generalized GARCH-based unit root test is the one proposed by NL (2015). The Cook (2008) and the NL (2013) are special cases of the NL (2015). The test regression proposed by NL (2015) for the GARCH-based unit root test that includes two endogenous breaks and a time trend is given below (see NL, 2015, pg. 396):

$$y_t = \lambda_0 + \lambda_1 t + \rho y_{t-1} + \sum_{i=1}^{k} D_i B_{it} + \varepsilon_t; \qquad i = 1,\ldots,k \tag{1}$$

where y_t denotes the series under consideration; t is a time trend; $B_{it} = 1$ if $t \geq T_{B_i}$ and $B_{it} = 0$ otherwise. The parameter λ_0 represents the intercept, λ_1 is the time trend coefficient, ρ is the autocorrelation coefficient and D_i is the break dummy coefficient. The underlying null hypothesis for the test is that there is unit root; that is, $H_0: \rho=1$. However, for the purpose of empirical application, an alternative specification as given below is used as the test regression:

$$\Delta y_t = \lambda_0 + \lambda_1 t + \delta y_{t-1} + \sum_{i=1}^{k} D_i B_{it} + \varepsilon_t; \qquad i = 1,\ldots,k \tag{2}$$

where $\delta = (\rho - 1)$ and Δ, as usual, is the first difference operator. In equation (2), the null hypothesis of unit root given as $H_0: \delta=0$ is tested against the alternative hypothesis of stationarity denoted as $H_1: \delta < 0$.

The NL (2013) is obtained by restricting $\lambda_1 = 0$ in equation (2). Therefore, the test regression for NL (2013) can be written as:

$$\Delta y_t = \lambda_0 + \delta y_{t-1} + \sum_{i=1}^{k} D_i B_{it} + \varepsilon_t; \qquad i = 1, \ldots, k \tag{3}$$

In other words, the main distinction between the NL (2013) and that of NL (2015) is the inclusion of a time trend in the latter. Similarly, to derive the Cook (2008) GARCH-based unit root test from equation (2), the parameters for both the trend term and structural breaks are restricted to zero and the resulting equation is given below:

$$\Delta y_t = \lambda_0 + \delta y_{t-1} + \varepsilon_t; \tag{4}$$

One major difference between the standard unit root tests and the GARCH-based unit root lies in the way the error term is treated. In the case of the latter, as the term implies, rather than assuming a white noise error term, the ε_t is assumed to follow a GARCH process. This may be valid for series that are available at a high frequency such as financial series which tend to exhibit random walk as well as conditional heteroscedasticity. Bollerslev (2001) succinctly highlights some of the inherent features of financial series and why it is important to account for these features when modelling and forecasting the series.

For computational simplicity, the ε_t follows the first-order generalized autoregressive conditional heteroscedasticity model, denoted as GARCH (1, 1) as shown below:

$$\varepsilon_t = \eta_t h_t^{1/2}; \tag{5a}$$

$$h_t = \phi + \alpha \varepsilon_{t-1}^2 + \beta h_{t-1} \tag{5b}$$

where $\varepsilon_t \sim \text{NID}(0,1)$; $\phi > 0$; $\alpha \geq 0$; and $\beta \geq 0$. Since we are using endogenously determined structural breaks as the break dates are unknown, the T_{B_i} has to be estimated and the resulting estimates are used for the unit root testing. In this paper, we follow the Bai and Perron [BP] (2003) multiple structural break test to determine the break dates.[2] We favour the use of BP test in determining the breaks as it allows for a maximum of five structural breaks in time series (see also, NL, 2015). It also involves a sequential application of $\sup F_T\left(\ell+1|\ell\right)$ test which is assumed to work best in selecting the number of breaks. The BP (2003) test provides the following procedure to estimate the number of breaks in a time series data.

i. Consider a model and estimate with a small number of breaks or without breaks.

ii. Then, perform parameter constancy tests for each of the sub-samples (those obtained by cutting off at the estimated breaks), adding a break to a sub-sample associated with a rejection with the test $\sup F_T\left(\ell+1|\ell\right)$.

iii. Repeat this process and increase ℓ sequentially until the test $\sup F_T\left(\ell+1|\ell\right)$ fails to reject the null hypothesis of no additional structural changes.

The estimated endogenous structural breaks obtained through the BP (2003) process are then incorporated in the relevant test regressions.

3.0 Data and Preliminary Analyses

We utilize daily data on global agricultural grains' futures prices for Corn, Oats, Rice, Soybean and Wheat over the period of 1986 to 2015 which are downloadable from the database of the Chicago Mercantile Exchange Futures Database (https://www.quandl.com/data/CME). We provide both graphical analyses as well as descriptive statistics to tease out the relevant statistical features of the considered series. As expected, all the series under consideration appear to follow a modest time trend and there is evidence of shifts in the trend (see figure 1). We further test for the significance of the time trend and structural breaks. As reported in Table 1, we find that the time trend coefficients for all the selected commodity prices are statistically significant and positive implying that, on average, the prices are fairly trending

[2] In any case, as noted by NL (2015), the manner in which structural breaks is chosen does not make the test unstable as long as there is a time trend in the test regression.

upward. Similarly, the BP test used to determine the presence of multiple breaks reveals the presence of structural breaks in the series under examination (see Table 2). Interestingly, we allowed for a maximum of two breaks and the test picked the maximum for all the series. In other words, the test resoundingly confirms the presence of structural changes in agricultural grains prices. Therefore, in testing for unit root of these series, there is need to account for both time trend and structural breaks. The results of these formal tests further reinforce our observations from the graphs presented.

Also, we test for the presence of heteroscedasticity using the Engle's (1982) ARCH LM test and the results confirm that the daily prices are heteroscedastic regardless of the lag length (see Table 1). This is corroborated by the skewness and kurtosis statistics which suggest that all the series seem non-normal.

All these inherent statistical features of the agricultural commodity prices appear to favour the underlying assumptions for the implementation of the GARCH-based unit root test. In the section that follows, we subject the selected series to both the standard unit root tests as well as the GARCH-based unit root tests.

Table 1: Descriptive Statistics

	CORN	OATS	RICE	SOYBEAN	WHEAT
Mean	318.367	201.551	9.382	778.602	431.090
Median	258.000	168.750	8.600	647.000	373.000
Maximum	830.250	600.00	24.420	1771.000	1295.000
Minimum	143.000	94.500	3.440	407.000	225.000
Std. Dev.	147.992	88.045	3.698	309.619	171.898
Skewness	1.55705	1.026	0.662	1.1488	1.290
Kurtosis	4.569	3.002	2.945	3.1890	4.1903
ARCH (6)	51.98***	161.12***	433.65***	535.74***	1394.94***
ARCH (12)	90.08***	167.95***	621.14***	752.83***	1787.99***
Trend	0.046***	0.029***	0.001***	0.102***	0.052***
Observations	7241	7225	7202	7243	7243

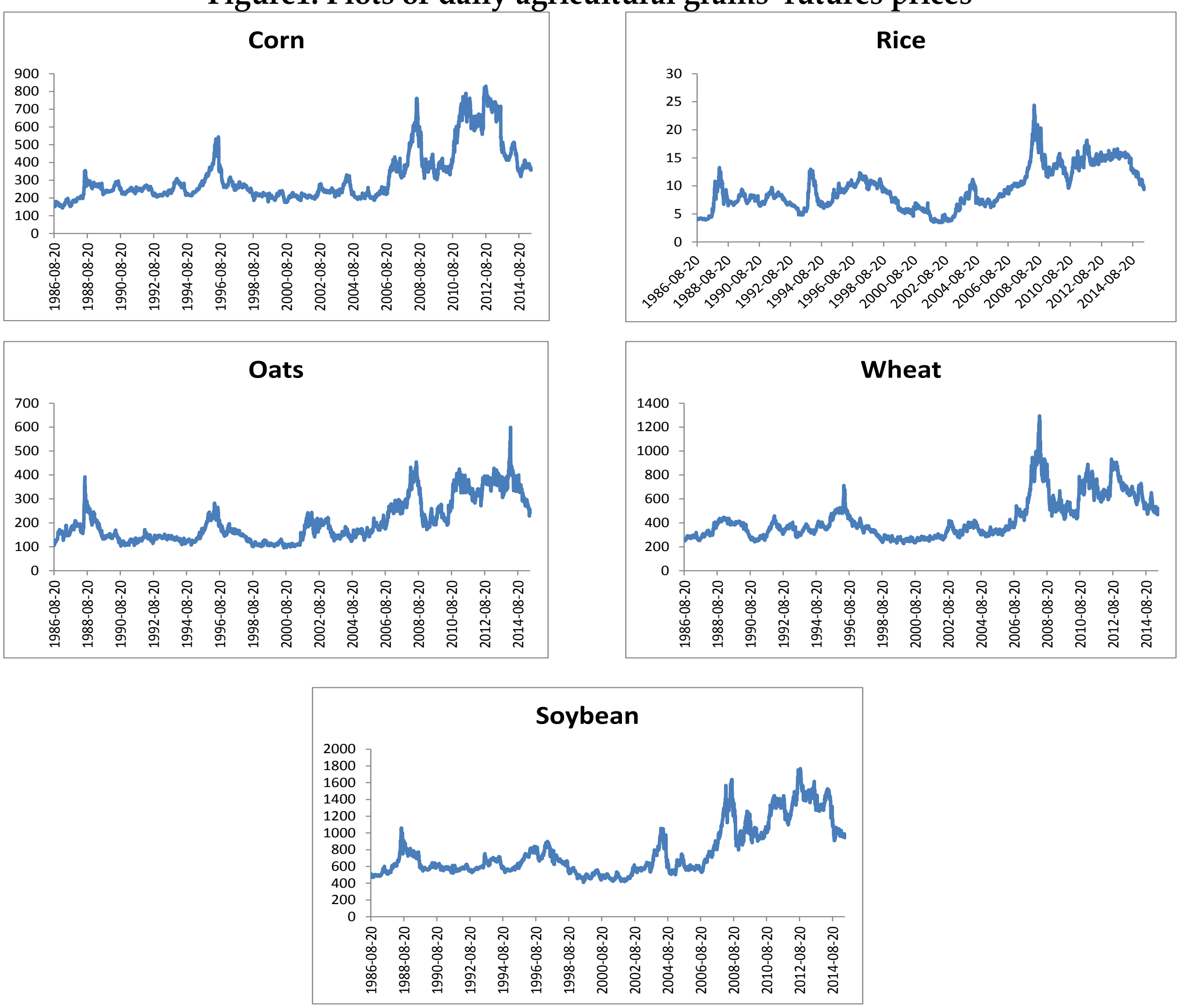
The results presented for ARCH test represent the nR^2 chi-squared statistic. Also, Trend indicates the trend coefficient in the OLS regression of each variable with constant and trend; while *** implies rejection of null hypothesis at 1% level of significance.

Table 2: Bai-Perron Multiple Structural Breaks for Agricultural grains' prices

Country	T_1		T_2		NSB
	$\sup F_T(\ell+1\|\ell)$	Break Date	$\sup F_T(\ell+1\|\ell)$	Break Date	
Corn	30.75	12/07/2013	278.32	23/07/2013	2
Oat	56.43	13/03/2014	376.74	17/03/2014	2
Rice	19.37	14/07/2008	47.49	21/07/2008	2
Soybean	23.49	13/08/2009	50.93	17/08/2009	2
Wheat	27.71	27/02/2008	284.95	12/03/2008	2

Note: NSB denotes number of significant structural breaks. The $\sup F_T(\ell+1|\ell)$ test statistics for the breaks are reported in parentheses. The critical values for $\sup F_T(\ell+1|\ell)$ at 10% level of significance as obtained from the Bai and Perron (2003) paper are 7.04and 8.51 respectively for $\ell = 1, 2$.

Figure1: Plots of daily agricultural grains' futures prices



4.0 Results of the Unit root tests

As previously noted, we consider both the non-GARCH-based (precisely ADF and PP) and the GARCH-based (that is, the Cook, 2008; NL, 2013 and NL, 2015) unit root tests. Starting with the former tests, we find that the unit root null hypothesis cannot be rejected for four series out of the five considered (see Table 3). Specifically, only OATS is confirmed to be stationary while other prices are found to be non-stationary. Judging by these tests, one may conclude that agricultural grains prices are non-stationary. However, when we extend the test to the GARCH-based unit root tests, we are able to reject the null hypothesis of unit root for at least three [i.e., Corn, Oats and Wheat] out of the five considered agricultural grains prices. Nonetheless, rice is consistently non-stationary across the different unit root tests. In sum, the non-rejection of unit root for Corn, Oats and Wheat using ADF and PP [which are consistently rejected under the GARCH-based unit root tests] may be due to the presence of conditional heteroscedasticity, time trend and structural breaks.

Note that the underlying GARCH model used for the results presented in table 3 is the GARCH (1, 1) model. To evaluate robustness of the GARCH-based unit root test, we further subject the conditional variance equation of the GARCH-based unit root tests to different lag orders namely GARCH (1,2), GARCH (2,1) and GARCH (2,2). In essence, we test whether the GARCH-based unit root test is sensitive to the choice of lag combination or not. The results obtained are reported for the Cook (2008), NL (2013) and NL (2015) are presented in Tables 4, 5 and 6 respectively. We find that, in terms of magnitudes of test statistics as well as number of rejections, the results of the different variations of lag orders considered are similar to GARCH (1,1) model. Thus, the GARCH-based unit root test appears robust to lag orders of the GARCH model. In other words, the test is not sensitive to the lag order of the GARCH model.

We also plot the conditional standard deviations of the series as presented in figure 2 below for the respective series. Interestingly, the most notable spikes on the graphs coincide with the structural break points as reported in Table 2. This behaviour further strengthens the significance of accounting for structural breaks when dealing with agricultural grains prices.

Therefore, judging by the results of the preliminary analyses, the unit root tests as well as the robustness checks, we can conclude that the unit root test for agricultural grains prices may be better modeled with GARCH process. In addition, it may be necessary to pre-test the existence of these statistical features when modelling with the agricultural commodities.

Table 3: Unit root tests

Series	Non-GARCH Based Unit Root Test		GARCH Based Unit Root Tests		
	ADF	PP	Cook (2008)	NL (2013)	NL (2015)
CORN	-2.676	-2.693	-8.878[a]	-3.626[a]	-3.073[a]
OATS	-3.548a	-3.524[a]	-7.486[a]	-6.999[a]	-6.251[a]
RICE	-2.658	-2.737	-2.785[a]	-1.532	-2.363
SOYBEAN	-2.766	-2.677	-3.263[a]	-2.586	-2.591
WHEAT	-3.188	-3.206	-5.028[a]	-5.550[a]	-5.523[a]

Note: [a] denotes 5% level of statistical significance. The ADF and PP tests include both intercept and time trend. The critical value for rejection of unit root null hypothesis in Augmeted Dickey Fuller (ADF) and Phillip - Perron (PP) tests at 5% level of significance is -3.41.The critical values for the GARCH-based unit root tests at the 5% level given as -2.00 for Cook (2008) and -2.87 for NL(2013) and NL (2015).

Table 4: Robustness Checks for Cook (2008) Test

Series	GARCH (2,1)	GARCH (1,2)	GARCH (2,2)
CORN	-8.940[a]	-8.970[a]	-8.206[a]
OATS	-7.083[a]	-7.567[a]	-5.749[a]
RICE	-2.717[a]	-2.719[a]	-2.636[a]
SOYBEAN	-3.437[a]	-3.424[a]	-3.099[a]
WHEAT	-4.937[a]	-4.891[a]	-4.892[a]

. Note: [a] indicates rejection of null hypothesis of unit root

Table 5: Robustness Checks for NL (2013) Test

Series	GARCH (2,1)	GARCH (1,2)	GARCH (2,2)
CORN	-3.582[a]	-3.532[a]	-3.524[a]
OATS	-6.641[a]	-7.094[a]	-5.443[a]
RICE	-1.515	-1.514	-1.189
SOYBEAN	-2.588	-2.664	-2.414
WHEAT	-5.476[a]	-5.491[a]	-5.522[a]

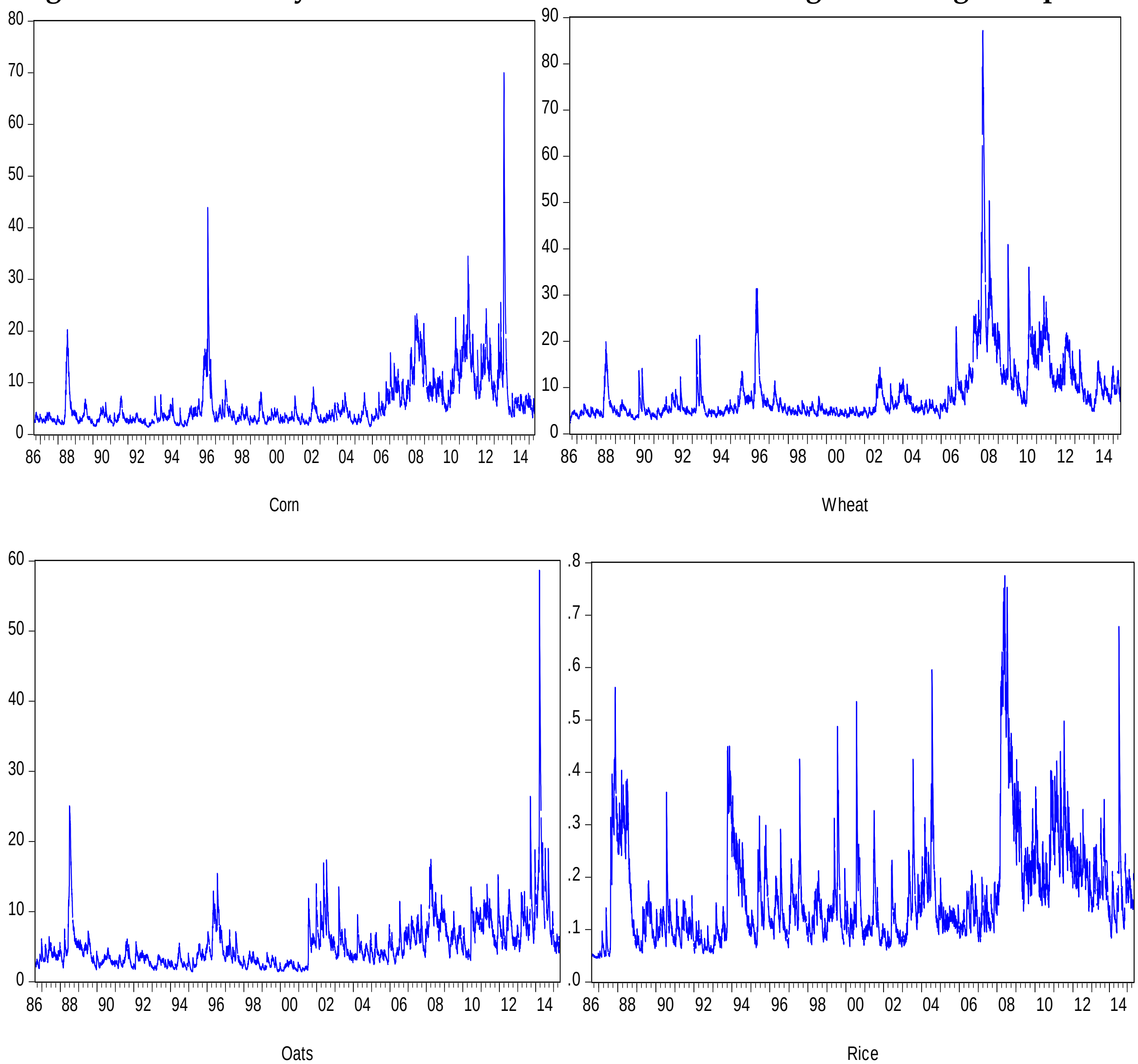
Note: [a] indicates rejection of null hypothesis of unit root

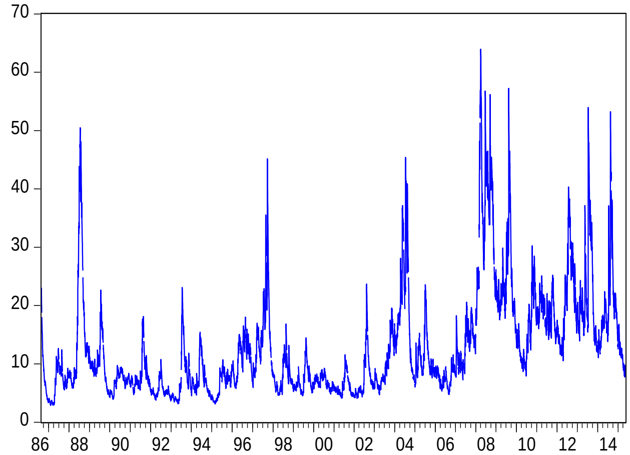
Table 6: Robustness Checks for NL (2015) Test

Series	GARCH (2,1)	GARCH (1,2)	GARCH (2,2)
CORN	-2.984[a]	-2.956[a]	-2.764
OATS	-6.155[a]	-6.305[a]	-6.098[a]
RICE	-2.339	-2.342	-1.934
SOYBEAN	-2.594	-2.672	-2.416
WHEAT	-5.454[a]	-5.468[a]	-5.550[a]

Note: [a] indicates rejection of null hypothesis of unit root

Figure2: Plots of daily conditional standard deviations for agricultural grains prices





Soybean

5.0 Policy Implications

The results of the unit root tests for agricultural grains prices have some far reaching policy implications. First, in forecasting the future paths agricultural grains prices, their past behaviour is expected to play a critical role. In other words, the future trends in agricultural grains prices are better predicted by their past values. Secondly, shocks to agricultural grains prices are more likely to have temporary effects and therefore, if there is any policy adjustment, its effects will be transitory rather than being long lasting. This observed behavioral pattern of shocks to the considered prices does seem to reflect the trends in the respective plots for the prices (see Figure 1). For all the series, whenever there was a shock, it was short-lived and thereafter reverted to almost the initial trend before the shock. Thirdly, because the shocks are temporary they are not likely to be transmitted to other macroeconomic variables such as inflation, exchange rate and consumption in a significant manner.

6.0 Conclusion

In this paper, we extend the application of the GARCH-based unit root tests namely the Cook (2008), NL (2013 and NL (2015) tests to daily agricultural grains prices from 1986 to 2015. From our preliminary results and graphical representations, we find that daily agricultural grains prices exhibit time trend, structural breaks and conditional heteroscedasticity. Drawing from the results of the unit root tests, the ADF and the PP tests are only able to reject the null hypothesis of unit root for Oats while other series are considered non-stationary. However, the GARCH-based unit root tests are able to reject the unit root null hypothesis for three commodities out of five namely Corn, Oats and Wheat. Thus, it may not be out of place to suggest that the unit root test for agricultural grains prices should be modeled in the presence of GARCH with structural breaks and time trend. In addition, it may be necessary to pre-test for the presence of structural breaks, conditional heteroscedasticity and time trend when modelling with agricultural grains prices. In terms of policy implications, contrary to the findings of Wang et al. (2014), Śmiech et al. (2015) and Zhang and Qu (2015); shocks to agricultural grains prices are more likely to be temporary and therefore, their past behaviour can be used in forecasting their future paths. In broad terms, any policy adjustment targeted at agricultural grains prices may not be long lasting; in other words, the initial impact of the adjustment is likely to die out over time.

References

Bai, J., Perron, P., 2003. Computation and analysis of multiple structural change models. Journal of Applied Econometrics 18, 1–22.

Bollerslev, T., 2001. Financial econometrics: Past developments and future challenges. Journal of Econometrics 100, 41-51.

Cook, S., 2008. Maximum likelihood unit rooting test in the presence of GARCH: A new test with increased power. Communication in Statistics- Simulation and Computation 37(4), 756-765.

Engle, R., 1982. Autoregressive conditional heteroscedasticity with estimates of the variance of the U.K. Inflation. Econometrica 50, 987-1008.

Mishra, V., Smyth, R., 2014. Is monthly US natural gas consumption stationary? New evidence from a GARCH unit root test with structural breaks. Energy Policy 69, 258–262.

Narayan, P.K., Liu, R., 2011. Are shocks to commodity prices persistent? Applied Energy 88, 409-416.

Narayan, P.K., Liu, R., 2013. New evidence on the weak-form efficient market hypothesis. Working Paper. Centre for Financial Econometrics, Deakin University.

Narayan, P.K., Popp, S., 2010. A new unit root test with two structural breaks in level and slope at unknown time. Journal of Applied Statistics 37(9), 1425-1438.

Perron, P., 1989. The great crash, the oil price shock, and the unit root hypothesis. Econometrica 57, 1361-1401.

Perron, P., 1997. Further evidence on breaking trend functions in macroeconomic variables. Journal of Econometrics 80 (2), 355-385.

Salisu, A.A. and Adeleke, A.I. (2016). Further application of Narayan and Liu (2015) unit root model for trending time series. Economic Modelling, 55, 305–314.

Salisu, A.A., Fasanya, I.O., 2013. Modelling oil price volatility with structural breaks. Energy Policy 53, 554 –562.

Salisu, A.A., Mobolaji, H., 2013. Modeling returns and volatility transmission between oil price and US–Nigeria exchange rate. Energy Economics 39, 169–176.

Salisu, A.A., Ndako, U.B., Oloko, T.F. and Akanni, L.O. (2016). Unit root modeling for trending stock market series. Borsa Istanbul Review, 16(2), 82-91.

Śmiech, S., Papież, M., Dąbrowski, M., 2015. Does the euro area macroeconomy affect global commodity prices? Evidence from a SVAR approach. International Review of Economics and Finance 39, 485–503.

Strazicich, M.C., Lee J., Day, E., 2004. Are countries converging among OECD countries? Time series evidence with two structural break. Journal of Macroeconomics 26, 131-145.

Wang, Y., Wu, C., Yang, L., 2014. Oil price shocks and agricultural commodity prices. Energy Economics 44, 22–35.

Zhang, C., Qu, X., 2015. The effect of global oil price shocks on China's agricultural commodities. Energy Economics 51, 354–364.

Zivot, E., Andrews, K., 1992. Further evidence on the great crash, the oil price shock, and the unit root hypothesis. Journal of Business and Economic Statistics 10, 251–270.