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Price Volatility Spillovers Among Major Wheat Markets in the World

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ABSTRACT: *This research determined price volatility spillovers among major wheat markets in the world using time series data (1966-2018) of six major wheat producing countries in the world. The data were sourced from FAO and UNCTAD databanks and were analyzed using descriptive statistics, multiple regression, unit root test and GARCH models. The findings showed that there is low and high persistence in the wheat prices of Canada and USA; and, Australia and India, respectively. Thus, it was established that the prices in the former markets were characterized by short memory; the effect of shock is temporary as the prices return to the attractor level within a short period. However, bad news on the prices of the latter markets has pronounced effect and takes a longer period for the price series to normalize. On the other hand, French and Chinese market price series exhibited an explosive pattern; the price series have infinite memory and the effect of innovation is permanent as price series will not normalize. Therefore, it can be concluded that the future trade of wheat is useful in the market given the persistence behavior of the prices as their price trends are tailored towards a rational expectation rather than a naïve expectation. However, for the market prices that are explosive, the market participants should focus on rational market expectation as a trade barometer.*

Keywords*: Price, volatility, wheat, spillovers, markets.*

INTRODUCTION

Owing to improvements in some factors influencing food demand, there has been an upward trend in the price of agricultural commodities in recent years (Barcena *et al*., 2011; Gozgor, 2019). The rise in the purchasing power of large segments of the population in countries such as China and India and the transition towards a more westernized diet are among the most important changes. In the past decade, the market trend for most agricultural commodities has been an upward one (Barcena *et al*., 2011; Abebe *et al*., 2020).

The latest round of price rises has concentrated focus on the volatility issue and its causes (Barcena *et al*., 2011; Sendhil *et al*., 2013; Guo and Tanaka, 2019). Volatility in prices creates uncertainty that can endanger agricultural production and have a negative effect on farmers' welfare (World Bank, 1997; Sendhil *et al*., 2013; Tanaka and Guo, 2020). In the current context, two essential questions arise. The first is how much of this increase can be attributed to the volatility created by short-term factors, and how much as a result of structural factors, to higher-level price convergence. The other is the role of various factors on volatility. These factors include speculation in the raw materials markets, uncertainty of the rate of the world economy's recovery, implementation of trade-restriction steps, decline in the value of the dollar, overreaction of agents in markets to reports of less than anticipated harvests, among others.

Volatility connotes two principal concepts in conventional economic theory: variability and uncertainty; the former defines general movement, while the latter applies to unpredictable movement (Prakash, 2011; Gouel *et al.*, 2016). As households and planning agencies are better able to cope with predictable variations, the key problem is sudden shifts or "shocks". Traditional policy prescriptions and coping processes are likely to fail when shocks reach a certain critical size or threshold and remain at those levels (Wolf, 2005; Subervie, 2008; Čermák *et al.* 2017; Taghizadeh-Hesary *et al*., 2019). Volatility reflects the directionless variability of an economic variable, i.e. the dispersion of that variable over a given time period, according to Prakash (2011), Santeramo and Lamonaca (2019).

Often, mainstream discourse confuses volatility with high prices. It is possible for prices to be high as a matter of logic, but display little flexibility, or to be low but variable. Price levels and volatility appear to be positively correlated in practice, partially because a low carryover from the past decreases current availability, exerts upward price pressure, and reduces the likelihood of using inventory to satisfy positive demand or negative supply shocks, thereby raising volatility (Gilbert and Morgan, 2010; Haile *et al*., 2016).

For the function of a competitive market, regular price fluctuations -"day-to-day" or "normal volatility" - are both typical and required. The essence of the price system is that price rises when a commodity becomes scarce, thereby causing a decrease in consumption and signalling further investment in that commodity's output. It is important to consider why prices have risen in order to better counteract the shortage (Grossman, 1976; Wang, 2009; Degiannakis *et al*., 2022). Prakash (2011) and Hau *et al*. (2020) said that as market fluctuations become increasingly volatile and precipitous, the efficacy of a price mechanism starts to break down, and eventually reaches the point of redundancy when prices experience "extreme volatility" or "crisis".

The current high volatility in the demand for agricultural raw materials has significant economic consequences for countries specializing in the export of such materials. Using market data from the 18th century, Jacks *et al*. (2009), Bohl and Sulewski (2019) and Degiannakis *et al.* (2022) concluded that volatility in the prices of raw materials has always been higher than that of manufactured goods. Consequently, reliance on the export of a few commodities is a fundamental cause of trade instability among countries specializing in their production, which makes them economically more vulnerable. Volatility in the prices of agricultural raw materials can have serious consequences for countries: losses in economic efficiency, higher food insecurity, higher levels of malnutrition, negative impacts on the balance of trade, possible social unrest and higher risks for producers, particularly small-scale producers, owing to the uncertainty of expected income levels.

Crisis periods and intense volatility highlight the challenge of forecasting price fluctuations of agricultural commodities and have reinforced the need to consider their behaviour. For developing countries that depend on commodity exports or import significant amounts of food, clarification of the characteristics of commodity prices - especially trends - is crucial. Deaton (1999), Stigler (2011) and Sukati (2017) stressed that to build effective policy, a better understanding of commodity prices is necessary. This knowledge can help governments and development agencies form policies and determine which goods need attention. Moreover, understanding commodity prices at the producer level helps people make key decisions about which crops to grow.

In addition, the modern marketplace's complexity has put exceptional demands on reliable and timely information on trends in commodities and on external drivers affecting market performance. It is argued that the lack of accurate and up-to-date information on crop supply and demand and export availability has been among the root causes of recent market volatility. The challenge is widespread. The ability to analyze the mass of sometimes conflicting and variable-quality data and to disseminate the resulting analyses have not kept pace, particularly in the public, free-access field, despite the increase in the volume of raw data and the higher speed of information transmission over recent years.

Risk and impact asymmetry are created by crisis and extreme volatility, which hinder development, accentuate poverty, lead to malnutrition, and increase political instability and the risk of internal conflict. The need to grasp the complexities of the dynamics of commodity prices has therefore become more urgent against the backdrop of current developments to abolish conventional governmental stabilization schemes (i.e. price bands and market intervention) in favor of globalized market transactions. In comparison to previous years, when agents concentrated solely on spot prices, they now have to deal with a broad range of complex factors, including derivatives markets, futures and options, normal backwardness phenomenon, maturity effects, and the correlation between spot prices and futures.

Thus, based on this thrust, this research aimed at exploring the insight of wheat price volatility and spillovers in the global market given that the crop is the most important and widely consumed cereal in the world. The specific objectives were to determine the price trends and their relationship with market arrivals, and price volatility of wheat among the major producing countries in the globe.

RESEARCH METHODOLOGY

Annual time series data of 37 years (1981-2018) sourced from FAO and UNCTAD databanks were used for the study. The data covered price series, production quantities and consumer price index (CPI) of six major wheat producing countries *viz*. Australia, Canada, China, France, India and USA. The prices and quantities; and, CPI were sourced form FAO and UNCTAD data bases respectively. The first and second objectives, respectively, were achieved using descriptive statistics, OLS and Autoregressive estimated multiple regression model, and Generalized Autoregressive Conditional Heteroscedastic (GARCH) model.

Model Specification

1. *Multiple regression*

$$P_t = \alpha + T_t + \varepsilon \qquad (1)$$

Where, $P_t\ is\ price\ at\ time\ 't'$, $\alpha\ is\ constant$, $T_t\ is\ time\ trend\ at\ time\ 't'$ and $\varepsilon\ is\ noise$

2. *Autoregressive model*

$$P_t = \alpha + P_{t-1} + Q_t + \varepsilon \qquad (2)$$

Where, $P_t\ is\ price\ at\ time\ 't'$, $\alpha\ is\ constant$,

$P_{t-1}\ is\ price\ at\ lag\ 'one'$,

$Q_t\ is\ market\ arrival\ at\ time\ 't'$, and

$\varepsilon\ is\ white\ noise$

3. The KPSS test

A unit root test in which the null hypothesis is contrary to that in the ADF test is the KPSS test (Kwiatkowski, Phillips, Schmidt and Shin). The series in question is stationary under the null; the solution is that the series is I (1). The basic idea behind this test statistic is very simple. If y_t can be written as $y_t = \mu + \mu_t$, where μ_t is a stationary zero-mean process, then not only does the sample average of y_ts provide a consistent μ estimator, but a well-defined, finite number is the long-run variance of μ_t. The alternative does not possess any of these properties. The test itself is based on the formula below:

$$\eta = \frac{\sum_{i=1}^{T} S_t^2}{T^2 \bar{\sigma}^2} \tag{3}$$

Where $S_t = \sum_{s=i}^{t} e_s$ and $\bar{\sigma}^2$ is an estimate of the long-run variance of $e_t = (y_t - \bar{y})$. This statistic has a well-defined (non-standard) asymptotic distribution under the null, which is free of nuisance parameters and has been simulation-tabulated. The numbers diverge according to the alternative. As a result, a one-sided test based on η can be built, where if η is greater than the required critical value, H_o is rejected.

4. GARCH model

The representation of the GARCH (*p*, *q*) is given as:

$$Y_t = \alpha + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \varepsilon_i \text{ (Autoregressive process)} \tag{4}$$

And the variance of random error is:

$$\sigma_t^2 = \lambda_0 + \lambda_1 \mu_{t-1}^2 + \lambda_2 \sigma_{t-1}^2 \tag{5}$$

$$\sigma_t^2 = \omega + \sum_{i=1}^{p} \beta_i \sigma_{t-i}^2 + \sum_{j=1}^{q} \alpha_i \varepsilon_{t-i}^2 \tag{6}$$

Where Y_t is the price in the i^{th} period of the i^{th} market, p is the order of the GARCH term and q is the order of the ARCH term. The sum of ARCH and GARCH $(\alpha + \beta)$ gives the degree of persistence of volatility in the series. The closer is the sum to 1, the greater is the tendency of volatility to persist for a longer time. If the sum exceeds 1, it is indicative of an explosive series with a tendency to meander away from the mean value (Sadiq *et al.*, 2016a; Sadiq *et al*., 2016b; Sadiq *et al*., 2020).

RESULTS and DISCUSSION

Summary statistics of the selected market prices

An examination of Table 1 and Figures 1 and 2 showed a minimal inflation rate in the wheat prices of the selected markets as evidenced by the slight differences between the nominal values and their respective corresponding real values. The average annual nominal market prices of wheat per ton were $172.73 in the Australian market, $136.84 in the Canadian market, $416.19 in the French market, $191.84 in the Indian market, $150.82 in the USA market and $210.54 in the Chinese market. Thus, it can be suggested that the lowest and highest average nominal prices were observed in the French and Canadian markets, respectively. The variance in the prices may owe to grading, quantity of market arrival and consumerism of importing nations in the global wheat market. The minimum values of the average nominal wheat prices varied from $62.00 in the Canadian market to $134.20 in the Indian market while the maximum values of the average prices varied from $273.90 in the Canadian market to $1309.50 in the French market. Besides, Indian wheat prices have the lowest standard deviation value ($52.19) while the French market has the highest standard deviation of price value ($427.70). A similar cross-examination of the price pattern for soft wheat for some selected European countries was done by Bórawski *et al.* (2018).

Furthermore, it was observed that price instability tends to be explosive in the French market, high in the Chinese market and moderate in the remaining markets. The entire market prices exhibit a positive skewness and this is reasonable since wheat inventories cannot be negative, thus placing a positive bias on the data. This suggests that all the market prices are asymmetrically distributed and the upper tails of the distributions were thicker than the lower tails. Sadiq *et al.* (2020) reported that ceiling price tends to introduce negative skewness while floor price tends to promote positive skewness. Thus, it can be inferred that the market forces determined the wheat prices of the selected markets in the global wheat market. The existence of positive skewedness can benefit policy design from a practical point of view, because positive price asymmetry means that one can be very confident in setting a minimum price level below which prices are unlikely to fall. On the other hand, the upper boundary is much more difficult to set, i.e. consumers or importing countries must be prepared for practically any price rise.

The kurtosis coefficients for all the selected market prices showed the tails of the distributions not to be thicker than the normal (<1). The market prices of Australia and USA; and, Canada, France, India and China, respectively, showed platykurtic (fat or short-tailed) and leptokurtic (slim or long-tailed) probabilities. Thus, it can be suggested that these markets did not exhibit extreme price values. Positive (negative) excess kurtosis means a fat (thin) tail distribution, whereas a value close to zero indicates a tail distribution similar to that of a normal distribution. In fact, prices can spike very high when inventory levels are extremely low or even zero. Therefore, the alternation between regular periods of low prices and occasional periods of turbulence contributes to a large kurtosis of prices. For the differenced price, all the market prices are asymmetrically distributed and the upper tails of the distributions are thicker than the lower tails (positive skewness), except for the French and Chinese markets (negative skewness). For the kurtosis, the tails of the distributions for French and Chinese market prices are thicker than the normal (>3) while that of the remaining markets are not thicker than the normal. Excess kurtosis is a feature of markets that exhibit extreme price values. The excess kurtosis depicted by the first differences of wheat prices in France and China may be attributed to the previously observed volatility that clustered around 1985 and 1992 for the former (Figure 3); and, 1987 to 1997 and 2004 to 2015 for the latter (Figure 4). Čermák *et al*. (2017) in their study observed that wheat prices were leptokurtic as evident by a fatter tail and longer peak that characterized the prices. Besides, Ismail *et al*. (2017) observed that the overall descriptive statistics distributions of price returns series were skewed, leptokurtic and platykurtic.

Table 1. Summary statistics of wheat prices in the selected markets.

Markets	Mean	Min	Max	SD	CV	Skewness	Kurtosis
			Nominal price				
Australia	172.73	102.80	327.10	55.47	0.32114	1.0580	0.60723
Canada	136.84	62.00	273.90	55.69	0.40702	0.85805	-0.13816
China	210.54	115.30	422.41	98.84	0.46944	0.90438	-0.71597
France	416.19	91.70	1309.50	427.70	1.0277	1.1500	-0.47884
India	191.84	134.20	283.90	52.19	0.27204	0.63247	-1.2761
USA	150.82	88.97	286.00	52.91	0.35083	1.0492	0.12413
			Real price				
Australia	166.63	94.84	313.46	54.78	0.32878	1.0170	0.41241
Canada	133.08	60.86	267.56	54.99	0.41326	0.90279	-0.11144
China	202.46	101.40	412.12	98.80	0.48801	0.90715	-0.71185
France	397.70	89.97	1268.90	402.21	1.0113	1.1781	-0.35982
India	178.13	122.90	273.49	49.25	0.27651	0.70681	-1.0899
USA	146.69	87.31	280.20	52.19	0.35579	1.0363	0.056079
			First difference price				
Australia	0.67784	-107.90	124.60	41.48	61.19	0.40785	1.4168
Canada	0.98110	-82.50	95.20	32.18	32.80	0.40524	1.9325
China	-1.0084	-226.90	50.60	44.13	43.76	-3.6528	16.811
France	-26.581	-1112.2	291.39	198.29	7.45	-4.4711	22.875
India	2.9721	-27.40	45.80	13.52	4.54	0.62401	1.9292
USA	0.90108	-70.00	81.00	30.49	33.84	0.11052	0.40685

Source: Authors’ own computation, 2020.

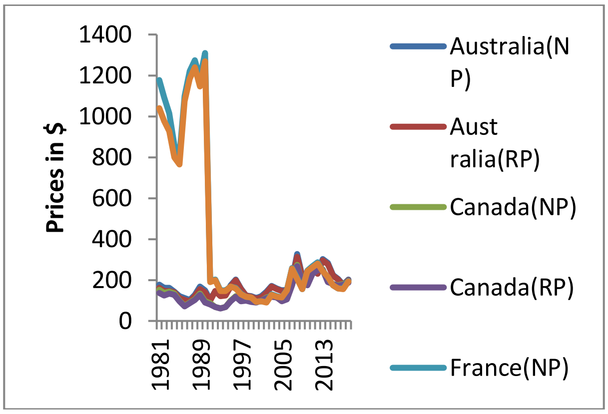

Figure 1. Nominal (NP) and Real (RP) Price trends of wheat.

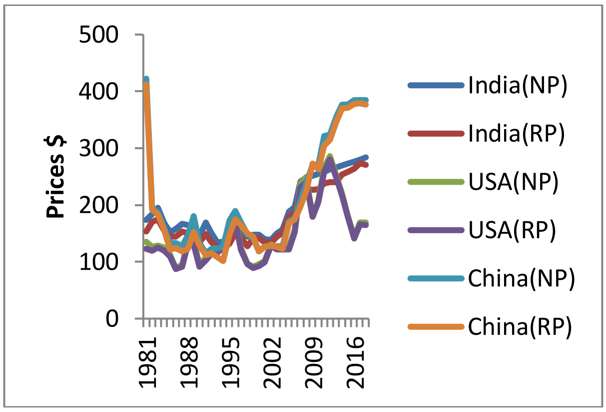

Figure 2. Nominal (NP) and Real (RP) price trends of wheat.

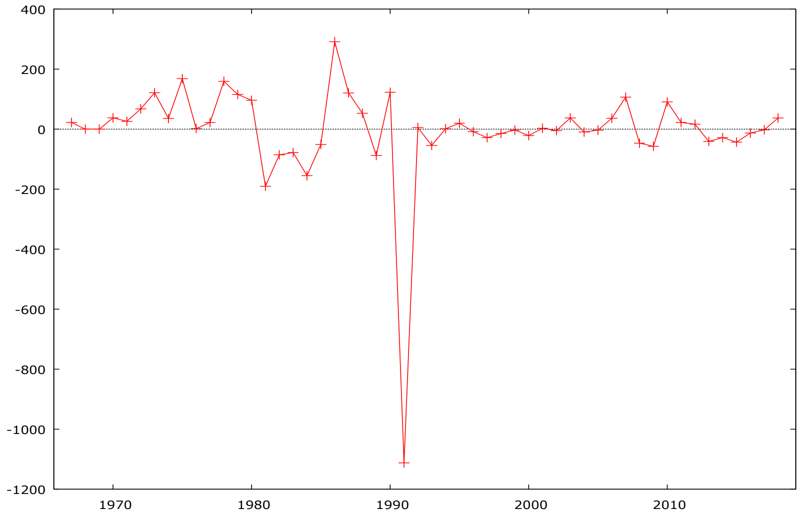

Figure 3. First difference price trend of French wheat.

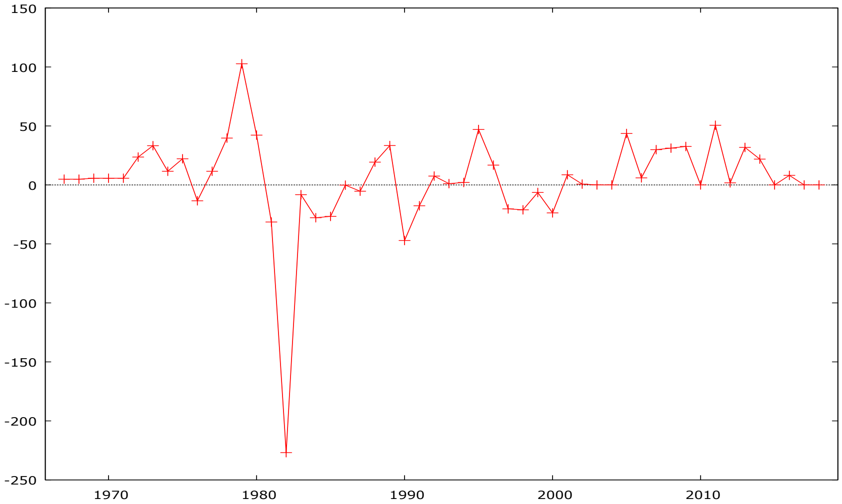

Figure 4. First difference price trend of Chinese wheat.

Price and market arrival trends

Except for French wheat prices, all the selected market prices increased significantly as indicated by the plausibility of their respective estimated time trend coefficient at 10% probability level (Table 2). However, the increase in the wheat prices of the Chinese market was not significant as evidenced by the non-plausibility of its estimated time trend at 10% significance level. Furthermore, the average market arrivals of all the selected markets increased as evidenced by their respective estimated time trend coefficients that are different from zero at 10% degree of freedom. The increase in the price was highest in the Chinese market though not significant, followed by the Indian, Australian, USA, and lowest in the Canadian market. However, the price plummeted in the French market. Likewise, increase in the average annual market arrivals was highest in China, followed by India, USA, France, Australia and least in Canada.

Relationship between price and market arrival

The relationship between the prices and market arrivals of the selected wheat markets were determined using ordinary least square. The diagnostic test results showed the residuals of the estimated models to be devoid of autocorrelation, Arch effect and heteroscedasticity as evidenced by their respective t-statistics that are not different from zero at 10% degree of freedom (Table 3). In addition, the specifications of the equations were adequate, the data had no structural break and the estimated parameters are stable i.e. do not change, as indicated by the non-significant of the RESET, chow and CUSUM test statistics at 10% degree of freedom, respectively. However, all the residuals of the estimated models were not normally skewed

Table 2. Price and market arrival trends of selected markets.

Items	Intercept	Time	R^2	D-W stat	ARCH test	Normality test
			Price trend ($)			
Australia	72.26(23.59) 3.062***	2.93(0.73) 4.04***	0.7066	1.827	0.184 [0.67]^{NS}	14.6 [0.00]***
Canada	67.493(37.40) 1.805*	2.21(1.10) 2.00*	0.7204	1.585	2.363 [0.12]^{NS}	14.11 [0.00]
China	111.88(197.66) 0.566^{NS}	4.12(4.72) 0.871^{NS}	0.8280	1.842	0.028 [0.86]^{NS}	31.1 [0.00]***
France	1260.26(364.10) 3.461***	−23.17(10.05) 2.304**	0.8523	1.954	0.017 [0.89]^{NS}	79.03 [0.00]***
India	87.58(48.69) 1.798*	3.31(1.27) 2.609**	0.9151	1.829	0.080 [0.77]^{NS}	6.174 [0.05]**
USA	69.73(32.46) 2.148**	2.36(0.96) 2.461**	0.7655	1.861	0.028 [0.86]^{NS}	5.556 [0.06]*
			Market arrival trend (Ton)			
Australia	8.53e+6(1.273e+6) 6.701***	313404(40630.6) 7.714***	0.5488	1.965	0.937 [0.33]^{NS}	2.248 [0.32]^{NS}
Canada	1.63e+7(2.01e+6) 8.112***	270000(62896.5) 4.293***	0.5375	1.821	0.459 [0.49]^{NS}	0.744 [0.69]^{NS}
China	3.83e+7(1.49e+7) 2.566**	1.81e+6(401465) 4.508***	0.9690	1.923	12.33 [0.26]^{NS}	1.037 [0.59]^{NS}
France	1.56e+7(1.76e+6) 8.889***	496592(54999.0) 9.029***	0.8385	2.305	0.052 [0.81]^{NS}	12.36 [0.002]***
India	1.14e+7(1.67e+6) 6.783***	1.63e+6(52431.6) 31.03***	0.9819	2.110	0.722 [0.39]^{NS}	1.353 [0.50]^{NS}
USA	5.57e+7(5.59e+6) 9.971***	70184.6(170675) 0.411^{NS}	0.4361	2.224	2.171 [0.14]^{NS}	1.233 [0.53]^{NS}

Source: Authors' own computation, 2020.
Note: *** ** * & ^{NS} means significant at 1, 5, 10% and non-significant respectively.
Values in ( ) and [ ] are standard error and probability value respectively.

as evidenced by the plausibility of their respective test statistics at 10% acceptable margin. Non-normality of residual is not considered a serious problem as data in their natural form are mostly not normally distributed. The cases of spurious correlation and regression were absent as indicated by the fair values of coefficient of determination (R^2) and the Durbin-Watson statistic values which were higher than their respective corresponding R^2, respectively. Thus, it can be concluded that the estimated parameters are reliable for future prediction with certainty and efficiency.

A perusal of Table 3 showed that on the average, all the selected market current prices had positive-significant relationships with their respective immediate lagged prices and negative relationships with most of the market arrivals except Australian and Indian market arrivals. However, only the market arrivals of France and USA had significant influence on their respective current prices as indicated by their respective market arrival estimated coefficients that are within the acceptable margin of 10%. Furthermore, based on R^2 coefficient, the influences of the explanatory variables on the current market prices of Australia, Canada, France, India, USA and China were 77.43, 76.64, 89.94, 85.91, 80.21 and 84.79% respectively.

In the Australian and Canadian markets, the marginal and elasticity implications of a unit increase in their respective immediate lagged prices will lead to increases in their current prices by 0.85 and 0.83%; and, $0.94 and 0.92% per ton, respectively. In the French market, the marginal and elasticity implications of a unit increase in its immediate lagged price will lead to an increase in its current price by $0.87 and 0.87% per ton while an increase in its market arrivals by a ton would results to a decrease in its current price by 0.37% per ton. In Indian and Chinese markets, for a dollar increase in their respective immediate lagged prices, their current prices will hike by $0.93 (0.90%) and $0.97 (0.94%) per ton, respectively. It was observed that in the US market, a $1 increase in its immediate lagged price will result in an increase in its current price by $0.99 (0.96%) per ton while a ton increase in its market arrivals will lead to a decrease in its current price by 0.39 per ton. Therefore, it can be inferred that glut in supply

Table 3a. Relationship between price and market arrivals.

Items	Australia	Canada	China	France	India	USA
Intercept	0.103(1.344)	3.218(2.086)	0.610(0.911)	7.177(2.731)	0.272(0.533)	7.200(3.484)
	0.076^{NS}	1.542^{NS}	0.669^{NS}	2.628**	0.511^{NS}	2.066**
P_{t-1}	0.826(0.086)	0.921(0.081)	0.940(0.056)	0.865(0.055)	0.901(0.081)	0.961(0.079)
	9.537***	11.28***	16.52***	15.70***	11.09***	12.14***
Y_t	0.046(0.095)	−0.166(0.133)	−0.015(0.048)	−0.373(0.147)	0.014(0.043)	−0.392(0.207)
	0.488^{NS}	1.244^{NS}	0.317^{NS}	2.527**	0.329^{NS}	1.888*
R^2	0.7742	0.7664	0.8479	0.8993	0.8590	0.8020
D-W stat	1.819[0.208]^{NS}	1.512[0.022]**	1.497[0.016]**	1.987[0.377]^{NS}	1.915[0.280]^{NS}	1.337[0.003]***
Autocorr. test	0.431[0.514]^{NS}	0.714[0.765]^{NS}	0.791[0.561]^{NS}	0.172[0.951]^{NS}	0.189[0.665]^{NS}	1.425[0.198]^{NS}
ARCH test	0.004[0.948]^{NS}	0.167[0.682]^{NS}	0.164[0.685]^{NS}	5.3e-5[0.994]^{NS}	4.635[0.462]^{NS}	0.486[0.485]^{NS}
Heterosc. test	5.049[0.409]^{NS}	2.139[0.829]^{NS}	8.783[0.118]^{NS}	7.431[0.114]^{NS}	1.386[0.975]^{NS}	4.219[0.518]^{NS}
RESET test	0.899[0.413]^{NS}	0.461[0.633]^{NS}	5.332[0.818]^{NS}	0.058[0.942]^{NS}	6.628[0.291]^{NS}	2.228[0.118]^{NS}
CUSUM test	0.185[0.853]^{NS}	1.727[0.904]^{NS}	0.884[0.381]^{NS}	-0.055[0.956]^{NS}	3.693[0.566]^{NS}	-0.006[0.994]^{NS}
Chow test	0.814[0.492]^{NS}	0.720[0.545]^{NS}	1.809[0.158]^{NS}	16.25[0.424]^{NS}	2.338[0.858]^{NS}	0.994[0.404]^{NS}
Normality test	6.625[0.036]**	8.952[0.011]**	20.64[0.000]***	43.65[0.00]***	13.03[0.001]***	6.538[0.038]**

Source: Authors' own computation, 2020

Note: *** ** * implies significance at 1%, 5% and 10% respectively

NS: Non-significant; and, values in ( ) and [ ] are standard errors and probability values

Table 3b. Elasticity and marginal effect estimates.

Market	Items	Coefficient	Mean ($\bar{X}$)	APP	MPP
Australia	P_{t-1}	0.826903	147.4753	1.025997	0.848400254
	Y_t	0.04659	17068157	8.87E-06	4.13022E-07
Canada	P_{t-1}	0.921152	122.5236	1.029274	0.948118073
	Y_t	-0.1666	23749656	5.31E-06	-8.84623E-07
China	P_{t-1}	0.940585	212.7715	1.034149	0.972705489
	Y_t	-0.0153	85394046	2.58E-06	-3.94364E-08
France	P_{t-1}	0.865602	523.7884	1.007024	0.871682246
	Y_t	-0.37357	28953738	1.82E-05	-6.80557E-06
India	P_{t-1}	0.901065	169.1156	1.031674	0.929605523
	Y_t	0.014343	55171723	3.16E-06	4.53585E-08
USA	P_{t-1}	0.961866	130.8477	1.024369	0.985306086
	Y_t	-0.39202	56862329	2.36E-06	-9.24071E-07

Source: Authors' own computation, 2020
Note: mean of the Pt for Australia, Canada, China, France, India and USA are $151.31, $126.11, $220.04, $527.47, $174.47 and $134.04

significantly affected price stabilization in France and USA markets. However, the Canadian and Chinese markets depict evidence of glut in supply but with no significant influence on price stabilization. Though non-significant, the positive sign associated with the market arrivals of Australian and Indian wheat prices showed relative balance in the supply and demand for their commodities.

Extent of price volatility

Literature has shown that volatility analysis should begin by ensuring that the prices under consideration are at the level of Gaussian pure white noise, that is, devoid of unit roots. According to Sukati (2017), it is important that other causes of non-stationarity, such as inflation effects and seasonal price changes in agricultural commodities, should be eliminated. In his research on the price volatility of common agricultural crops in South Africa, Jordan *et al.* (2007) also adopted this strategy, removing the impact of inflation and seasonal variation in the price series. Jordan *et al.* (2007), however, used South African crop prices as quoted by SAFEX, and seasonal price adjustments should not be a concern due to hedging by traders and speculators. In this case, price variation should mainly reflect production costs and market sentiments of traders in terms of subsequent production forecasts and risks therein, particularly when using spot prices. Following these claims, the analysis removes the impact of inflation on wheat prices before the unit root test is carried out by converting all selected market prices to actual prices. Also, Sukati (2017) in his study on maize price volatility in Swaziland eliminated the effect of inflation on prices. The KPSS unit root results showed all the selected market prices to be stationary at level as indicated by their respective tau-statistics which were within the plausible margin of tau-critical value at 5% probability level (Table 4). However, Ismail *et al.* (2017) and Čermák *et al.* (2017) found a contrary result in their study which is against the presumption test on volatility postulated by Sukati (2017).

Table 4. Unit root tests.

Markets	Stage	KPSS
Australia	Level	0.109^{st}
Canada	Level	0.142^{st}
China	Level	0.132^{st}
France	Level	0.146^{st}
India	Level	0.143^{st}
USA	Level	0.092^{st}

Source: Source: Authors' own computation, 2020
Note: KPSS tau critical level at 5% probability is 0.149.
st means stationary

A review of the results showed presence of Arch effect in the residuals of all the selected markets as indicated by the plausibility of Arch LM test statistic at 10% probability level (Table 5). In addition, the trend behaviour of all the price series residuals showed clustering effect as periods of high volatility tended to be followed by periods of high volatility; likewise, periods of low volatility tended to be followed by periods of low volatility over a long period of time (Figure 5). This behaviour is known as clustering volatility, thus

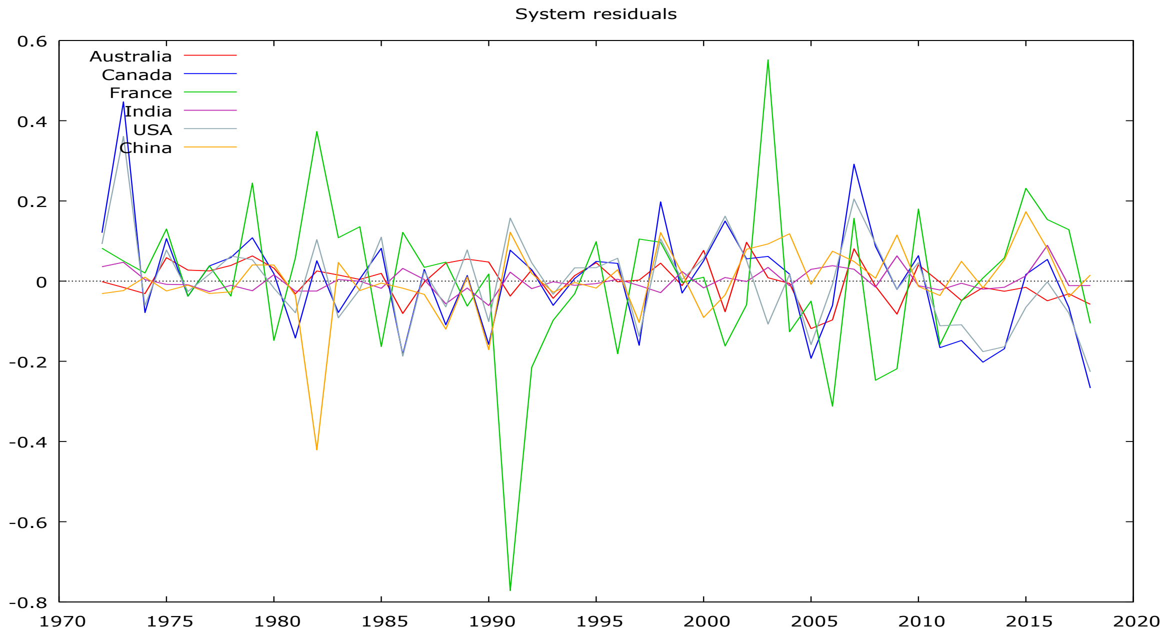

Figure 5. Clustering effect.

indicating that the residuals are conditionally heteroscedastic and can be represented by ARCH and GARCH model. Čermák *et al*. (2017) found a similar trend in their study on wheat price volatility modeling. Therefore, having satisfied the pre-conditions *viz*. ARCH and clustering effects, the GARCH model was estimated. In other words, the presences of Arch and clustering effects mean that wheat price volatility is time variant and hence amenable to the GARCH approach. In a related study, Ismail *et al*. (2017) established a similar result in their study on price volatility of food and agricultural commodities in Pakistan.

All the market prices were fitted with the same GARCH order i.e. GARCH (1,1) and their residuals were devoid of autocorrelation as indicated by their respective LM test statistics which were not different from zero at 10% degree of freedom (Table 5). However, except for the French and Chinese wheat prices, the residuals of the remaining market prices were normally distributed as indicated by their respective Chi^2 test statistics that were not different from zero at 10% significance level. Non-normality is not considered a serious problem as it aims at fulfilling statistical inference, thus the estimated model is reliable for future prediction. Furthermore, the results showed persistence volatility in the market prices of Australia, Canada, India and USA as indicated by the sums of their respective ARCH and GARCH term i.e. (alpha + beta) which were less than 1. The market prices of France and China showed an explosive volatility pattern as evidenced by the sums of their respective alpha and beta which were equal or greater than unity.

The empirical evidence showed that the current price volatility of the Australian price series is influenced by only family shock *viz.* ARCH effect. This implies that volatility in the current year price of the Australian market depends on the arbitrage about the previous year price of wheat in the Australian market. Thus, the marginal implication of a unit increase in information about the previous price trend of Australian wheat prices will lead to an increase in its current price volatility by 0.778%. The current year price volatility of the Canadian price series is influenced by international shocks. The international shocks owe to volatility in the market prices of Australia and India as evidenced by their respective parameter estimates that are within the acceptable margin of 10% probability level. Therefore, a unit increase in the prices of Australian and Indian wheat will trigger an increase in current price volatility of Canadian wheat by 0.49 and 0.39% respectively. The current price volatility of the French price series is influenced by information on its previous wheat price (an internal shock) and the market prices of USA (an external shock) as indicated by their respective estimated coefficients that were within the plausible margin of 10% significance level. Therefore, a unit increases in its previous price information and wheat price of USA will lead to an increase in current price volatility of France wheat by 1.0 and 0.99%, respectively.

In the Indian market, its current price volatility is influenced by information on previous year price arbitrage of its wheat and shocks from Australian and USA markets as evidenced by their respective parameter estimates that are within the acceptable margin of 10% significance level. Thus, the implication of a unit increase in price arbitrage information and prices of Australian and USA wheat will trigger an increase in the current price volatility of Indian wheat by 0.89, 0.27 and 0.36% respectively. The current price volatility in the US market is influenced by international shock *viz*. the Canadian market price as indicated by the plausibility of its respective parameter estimate at 10% degree of freedom. Thus, an increase in the wheat price of Canadian market by 1% will lead to an increase in the current price volatility of USA market by 0.68%. The current price volatility of the Chinese price series is influenced by speculation about previous year price trend of its market as indicated by its estimated coefficient that is different from zero at 10% probability level. Thus, an increase in price arbitrage about the previous price of Chinese wheat would result in an increase in its current price volatility by 0.98%. Generally, none of the market prices has its current volatility being influenced by their respective previous year price as evidenced by non-plausibility of their respective GARCH estimated coefficients at 10% probability level.

Table 5. Price volatility of wheat in the selected markets.

Items	Australia	Canada	China	France	India	USA
Arch Effect	33.5[7.1e-9]***	30.1[4.1e-8]***	28.16[1.11e-7]***	34.24[4.9e-9]***	34.46[4.4e-9]***	39.55[3.18e-10]***
		Variance equation				
Intercept	-	−2.057(0.889)	4.813(0.145)	-	1.753(0.333)	1.042(0.896)
	-	2.312**	33.19***	-	5.263***	1.163^{NS}
Australia	-	0.490(0.225)	-	−0.120(0.158)	0.269(0.138)	-
	-	2.178**	-	0.762^{NS}	1.949*	-
Canada	-	-	-	−0.053(0.168)	-	0.681(0.162)
	-	-	-	0.315^{NS}	-	4.194***
China	-	0.136(0.107)	-	−0.062(0.103)	-	−0.124(0.119)
	-	1.274^{NS}	-	0.605^{NS}	-	1.043^{NS}
France	-	0.051(0.039)	0.015(0.027)	-	0.041(0.028)	−0.036(0.031)
	-	1.273^{NS}	0.546^{NS}	-	1.474^{NS}	1.171^{NS}
India	-	0.387(0.228)	-	0.239(0.175)	-	0.277(0.256)
	-	1.696*	-	1.367^{NS}	-	1.082^{NS}
USA	-	0.285(0.193)	-	0.998(0.175)	0.363(0.127)	-
	-	1.474^{NS}	-	5.688***	2.851***	-
Alpha (0)	5.787(4.588)	0.014(0.016)	0.0077(0.0067)	0.00581(0.00585)	0.0065(0.0080)	0.015(0.015)
	1.261^{NS}	0.862^{NS}	1.149^{NS}	0.993^{NS}	0.806^{NS}	1.004^{NS}
Alpha (1)	0.778(0.367)	0.239(0.288)	0.976(0.339)	1.000(0.444)	0.888(0.454)	0.377(0.276)
	2.118**	0.830^{NS}	2.875***	2.251**	1.952*	1.365^{NS}
Beta (1)	8.06e-11(0.503)	1.11e-12(0.970)	0.024(0.163)	1.000e-12(0.067)	1.037e-12(0.558)	1.218e-12(0.729)
	1.60e-10^{NS}	1.14e-012^{NS}	0.145^{NS}	1.477e-11^{NS}	1.858e-12^{NS}	1.669e-12^{NS}
$\alpha + \beta$	0.778	0.239	1.00	1.00	0.888	0.377
GARCH fit	1,1	1,1	1,1	1,1	1,1	1,1
Normality	2.171[0.337]^{NS}	2.563[0.277]^{NS}	14.51[0.001]***	54.17[1.72e-12]***	2.34[0.57]^{NS}	4.226[0.121]^{NS}

Source: Authors' own computation, 2020

Note: *** ** * implies significance at 1%, 5% and 10% respectively

NS: Non-significant; and, values in ( ) and [ ] are standard errors and probability values

Therefore, it can be inferred that the future trade of wheat is useful in markets that have their prices characterized by persistent volatility while it is not useful in market prices characterized by explosive volatility pattern. Price series with low persistence volatility *viz.* the Canadian and US markets have a short memory and the effects of shock will dissipate rapidly in these markets, i.e. price shock normalized after a few periods. For markets with high persistence *viz*. Australia and India, their price series is characterized by a long memory, the same shock has a pronounced effect as a long time is required for the price to return to the normal level. However, for the French and Chinese price series which were explosive, their price series exhibit infinite memory and the shock effect is permanent and the prices will not return to the series attractor level. The closer the sum coefficients of Alpha and Beta is to 1, the more the price series displays a variation and the more unstable it appears to be. Market prices with explosive volatility, i.e. coefficient greater than 1, have non-stationary price series, implying that their mean or variance is time variant i.e. will change over time. The price series of markets with persistence volatility is stationary, meaning they have a time invariant/ fixed mean and variance. If a series is found to be non-stationary, little can be done to predict it; a sharp drop is as probable as a sharp rise (Stigler, 2011).

The reason for persistence volatility of the Australian, Canadian, Indian and USA markets may be due to supply-demand fluctuation of their commodities in the international markets. However, foreign market price shock due to cold trade war in the global wheat market may be the cause of explosive price volatilities in the French and Chinese markets. The price volatilities in all the selected markets tend to be spiky as evidenced by the large proportion of the ARCH coefficient over the GARCH coefficient.

In general, price series persistence volatility plays a key role and has very practical consequences for market participants. The persistence of a price series is also critical for modeling strategy, as non-stationary variables require non-standard statistical methods (Stigler, 2011). A similar result of high persistence, though in the short-run was established by Čermák *et al.* (2017) in their study on wheat price volatility modeling. In a related study, Dawson (2015) observed a highly persistent volatility of daily wheat feature prices on Euronext/London international financial futures and option exchange. In addition, Hau *et al.* (2020) reported high persistence in the volatility dynamics of the dependence between global oil and China’s agriculture.

CONCLUSION and RECOMMENDATIONS

Based on the findings, it can be inferred that the price volatilities of Australian and Indian wheat; and, Canadian and USA wheat were characterized by short and long memories, respectively. Thus, bad news on the prices of the former will dissipate rapidly while in the later markets it will take a long period before prices are normalized due to pronounced effect. However, price volatilities of the French and Chinese markets are characterized by infinite memory and the effect of innovation will be permanent. Generally, it can be inferred that the future trade of wheat in Australia, Canada, India and USA markets are useful. Therefore, the study advised that the wheat trades in France and China markets should be tailored towards rational market expectation and not naïve market expectation.

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