Black Sea Wheat Market Integration with the International Wheat Markets: Some Evidence from Co-integration Analysis

Kateryna Goychuk
PhD Student
Department of Agricultural and Applied Economics
University of Missouri, Columbia
kgoychuk@gmail.com

and

William H. Meyers
Howard Cowden Professor
Department of Agricultural and Applied Economics
University of Missouri, Columbia
meyersw@missouri.edu

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Abstract

In the last two years, Russia and Ukraine together exported an average of 29 million tons of wheat per year (USDA), and have become important players in the international wheat market. This paper examines the nature of the short- and long-run wheat price dynamics between Ukraine and Russia and other major wheat exporters - United States, European Union (EU), and Canada. For this purpose we use cointegration techniques (both the Johansen ML test and the Engel and Granger procedure) as well as the error correction model. The results suggest that Russian price series are cointegrated with those of the EU, but not with Canadian or U.S. wheat prices. Ukrainian prices series are found not to be cointegrated with other series. The estimated long-run price transmission elasticity between Russian and French (a representative country of the EU) wheat prices is equal to 1.07. We found the short-term relationship between Russia and EU also to be statistically significant. We show that after the price change occurs in the French price, Russian wheat price adjusts to the change within 6 months.

Introduction

Over the past few years and before the drought of 2010, the share of the Black Sea wheat exports in the world wheat trade has been steadily growing. In 2008-2010 Russia and Ukraine together exported an average of 29 million tons of wheat per year (USDA). This accounted for 21.3 percent of the world wheat exports in those two years (figure 1), and was greater than the exports of any of the other major exporters – US, Canada, EU-27, and Australia. Therefore, given the increasing significance of the Black Sea wheat region in the international wheat markets, it is important to learn more about its role in market behavior. The objective of this study is to investigate short- and long-run wheat price dynamics between Ukraine and Russia and other major wheat exporters - United States, European Union (EU), and Canada.

In this paper we address two major issues. The first question is whether the Black Sea wheat market is integrated with the wheat markets of the US, Canada, and EU. Second, we investigate the short run dynamics among the analyzed series, i.e. how fast Ukrainian and Russian wheat prices adjust to those of the US, Canada, and EU, if at all.

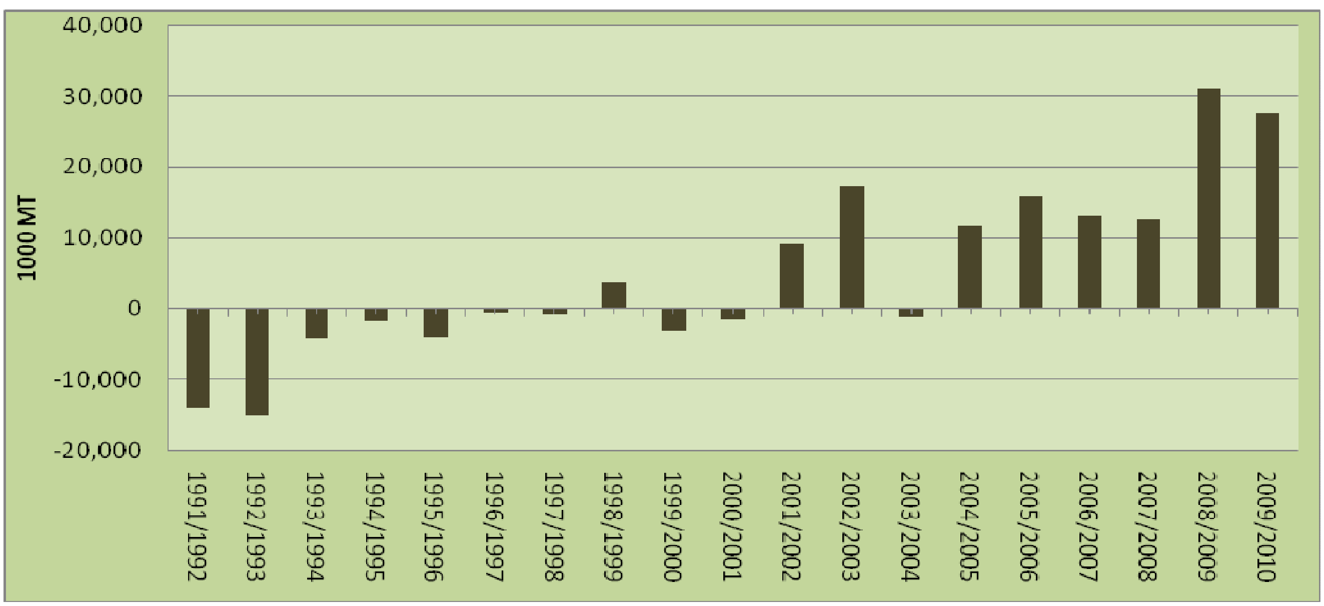

Figure 1. Dynamics of the Russian and Ukrainian wheat net exports (Source: USDA, June 2011).

Even though the price relationships in agricultural commodity markets have received a considerable amount of attention by economists in recent years due to the growing trend towards market liberalization across the globe, very little if any research has been done on the wheat prices of the Black Sea region.

To our knowledge only the study by Sagidova (2004) analyzes the wheat price dynamics between Ukraine and the USA before 2003. Her results suggested that two series were cointegrated. The short-term relationship, however, was found to be statistically insignificant. Another study by Ghoshray (2008) focused on the analysis of the price cointegration of the Ukrainian wheat and the U.S. corn prices. The findings suggested that there is no cointegration between the series. To our knowledge there are no studies that investigate the Russian wheat price series. Our study also contributes to the literature by estimating long-run price transmission elasticities that could be used to better link the wheat prices of the Black Sea region in modeling global wheat market behavior.

The rest of the paper is organized as follows: Section 2 highlights the conceptual framework of our study, Sections 3 and 4 focus on the description of the data and the econometric methods used to test for price dynamics between Ukrainian/Russian and the US, French, and Canadian wheat prices. Section 5 describes the major empirical results of the short- and long-run price analysis. Finally, section 6 discusses the conclusions and implications of the study.

The Conceptual Framework

The notion of price cointegration and, as a result, of market integration lies in the Law of One Price (LOP), according to which in an efficient market uniform goods must have only one price assuming absence of transportation costs or trade restrictions (Isard, 1977). This is the strong version of the LOP. It holds on the condition of spatial arbitrage, which suggests that if the prices of two identical goods have different prices in different locations, the higher prices will attract the arbitrageurs to take advantage of the existing profits till the point when the prices equalize across the different locations. Thus, in the short-run prices can deviate from one another, but in the long run they will be the same after accounting for the transportation costs (Listorti, 2008).

In reality, however, there are a number of factors that could affect the efficiency of the markets and/or price relationships between different goods, such as, transaction costs, market power, exchange rates, quality differences, etc. This results in a failure of most of the empirical tests to support the hypothesis of the LOP, which "might depend both on the strong assumptions underpinning it and on the inherent features of the empirical models used" (Listorti, 2008). Therefore, most economists tend to focus on testing market integration (weaker version of LOP), rather than adherence to it, and cointegration models are the most widely used for this purpose. In particular, under its weaker condition two spatially separated markets are considered to be integrated for a particular good if there is a long-run relationship between the prices for this good in different markets.

Data

In our empirical investigation we used monthly wheat FOB prices for the Russian Soft Wheat and Ukrainian Feed Wheat (Black Sea ports), Canadian Western Red Spring Wheat (St. Lawrence), US Soft Red Winter Wheat (Gulf ports), and French Soft Wheat (Rouen). The time span of our analysis is from July 2004 till October 2010. We assumed the French wheat price to be representative of the EU wheat price, since it is the biggest producer of wheat in the EU (Eurostat). All the series are quoted in nominal USD per ton and are expressed in logs. The series were obtained from the International Grains Council.

A visual inspection of the graph of the analyzed series in USD per ton suggests that all the series tend to move together over the analyzed period (Figure 2). The reason for the Canadian prices to be consistently higher than other prices is due to the differences in the quality between soft and hard wheat. We also did not detect a significant trend in the series.

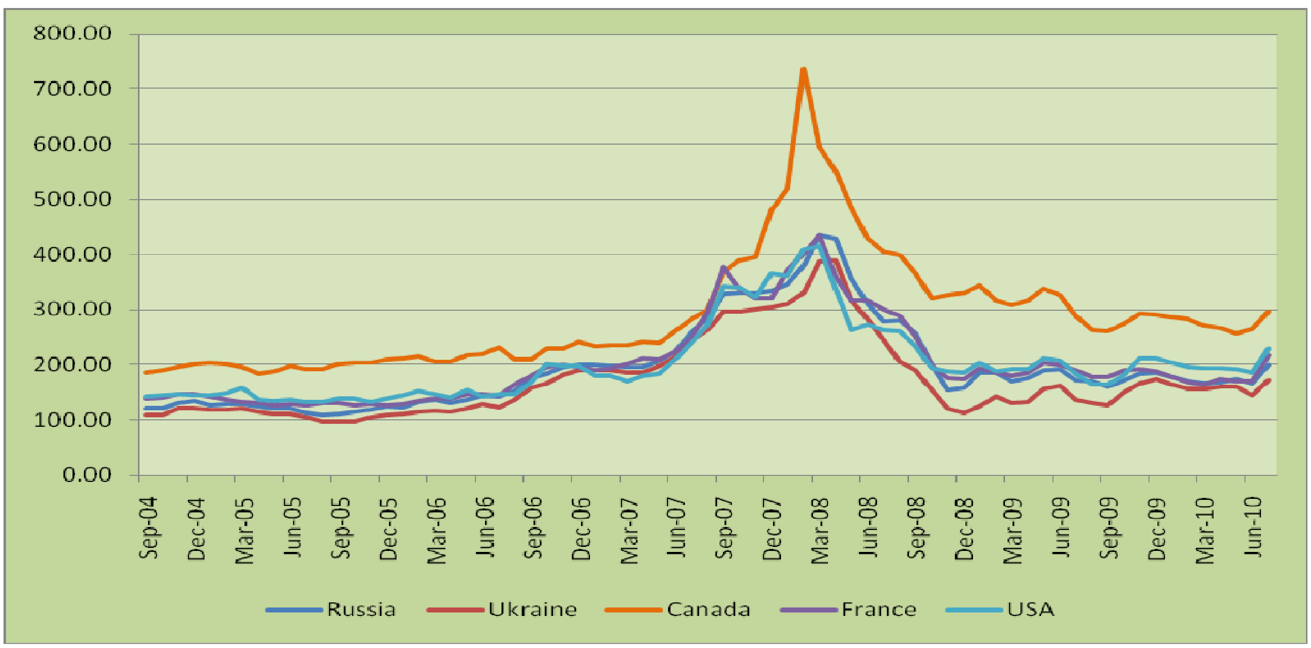

Figure 2. Comparison of wheat prices at different export points, $ per ton (Source: IGC)

The descriptive statistics and characteristics of the analyzed time series are provided in the Table 1, which shows evidence of positive skeweness. This is the sign that the price distributions have long upper tails, which is typical of most commodity price series. Additionally, the positive excess kurtosis indicates that the price distributions have more mass in the tails of the distribution relative to the normal case, which is also common for the commodity prices. The total number of observations is 74.

Table 1. Descriptive Statistics and Characteristics of the Price Series

Country	Wheat type	Min	Max	Mean	SD	Variance	Skewness	Excess kurtosis
Ukraine	Feed Wheat, Black Sea	97	390	174.23	72.59	5268.58	1.28	0.87
Russia	Soft Wheat, Black Sea	110	435	195.12	79.16	6266	1.37	1.25
Canada	Western Red Spring, St. Lawrence	184.18	736.195	290.84	105.32	11092.11	1.82	4.19
USA	Soft Red Winter, Gulf	133.16	415.295	204.61	69.38	4812.84	1.38	1.24
France	Standard Grade Wheat, Rouen	126.05	434.385	205.17	76.36	5830.82	1.19	0.58

Methodology

A variety of techniques have been used by the economists to analyze the short- and long-run dynamics of the price series. In order to test for the long-run relationship between Russian/Ukranian and US, Canadian, and EU prices we used both the Johansen maximum likelihood (ML) cointegration test (the primary one) and the Engel and Granger cointegration procedure (for the consistency check). Both of the methods are commonly used to test for cointegration. We ran the Johansen ML test both on the multiple series to estimate the total number of cointegrating relationships and on different pairs of the wheat price series. To investigate the short-term dynamics of the price series we developed Error Correction Models for each pair of price series that turned out to be cointegrated.

Unit-Root tests

To be able to test the price series for cointegration, we first need to check them for the presence of the unit root. For this purpose, the Augmented Dickey-Fuller (ADF), Philips Perron (PP), and Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) tests were conducted.

The main objective of the ADF ((Dickey et al., 1979) unit-root test is to test the null hypothesis that $\beta_1 = 0$ (i.e. Ho: series contains a unit root) in the following equation (Myer, 1997):

$$\Delta Y_t^{RUS} = a_0 + a_1 t + \beta_1 Y_{t-1}^{RUS} + \sum_{j=1}^{p} \gamma \Delta Y_{t-j}^{RUS} + \varepsilon_t \qquad (1)$$

where Y^{RUS} is the Russian wheat price in logarithms. Similar equations were run for the Ukrainian, US, Canadian and EU wheat log-price series.

The above equation includes the time trend t. In those cases when we checked for the unit roots in the time series with a drift or intercept only (i.e. excluding a time trend), t was not included.

The number of lags were estimated by minimizing the Akaike Information Criterion (AIC) starting with the 12 lags in the initial regressions. The correct choice of the lag length is important. If the number of lags is too small, the error terms will be serially correlated and the results of the tests will be biased. On the contrary, the more lags are added, the more degrees of freedom are lost.

The Philipps-Perron tests are similar to ADF ones and usually provide the same results. The advantage of the PP tests, however, is that they "incorporate an automatic correction to the ADF procedure to allow for autocorrelated residuals "(Brooks, 2002).

The KPSS unit root tests were run as a consistency check of the results obtained from the ADF and PP tests. As was mentioned before, both ADF and PP tests' null hypotheses assume non-stationarity of the series, which results in a low power of these tests to reject the null, unless there is strong evidence of the stationarity (Listorti, 2008). This might result in Type II errors. On the contrary, the KPSS test's null hypothesis is that the data is stationary. Due to these differences in the designs of the tests, KPSS is a good complement to the ADF and PP unit root tests. For example, if the ADF and PP tests fail to reject the null hypothesis, while KPSS rejects its null, the strong evidence of the unit root presence can be assured. If however, one of the tests does not support the evidence of another, further investigation of the series is needed (Cheung et al., 1994).

The next step was to test for co-integration. Two non-stationary series that are integrated of the same order are cointegrated if they have a long-run relationship and a linear combination of the series is stationary, even if they diverge in the short run. Moreover, if series are cointegrated it means that the weaker condition of the LOP holds.

Johansen maximum likelihood test

In the core of Johansen's procedure lies the VAR approach to cointegration. To obtain the test results, we, first, specify the VAR(k), there k is the number of lags (Hjalmarsson et al., 2007; Barassi et al., 2007):

$$P_t = \mu + A_1 P_{t-1} + \cdots + A_k P_{t-k} + \varepsilon_t \qquad (2)$$

where P_t is a *n x 1* vector of prices, and A_k is the matrix of the coefficients to be estimated. This equation is further converted into the following vector error correction model:

$$\Delta P_t = \mu + \delta t + \prod P_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta P_{t-i} \qquad (3)$$

where Δ denotes first difference, μ and δt are deterministic trends, Γ_i represents the dynamic effects, while Π captures the long-run effects of the analyzed series. The goal of the Johansen ML test is to estimate the rank of Π matrix, which represents the number of cointegrating relationships. If the rank is equal to $r<n$, it implies that there are r cointegrating vectors in the system.

One of the benefits of using the Johansen ML method is that it allows obtaining more than one cointegrating relationship. Another benefit is that the Johansen test, unlike the Engel and Granger procedure, allows for seasonality (Myer et al., 1997).

Residual-based test for co-integration

The Engle and Granger (1987) procedure consists of two steps. First, the long run relationship between the pairs of export log-prices is estimated:

$$P_t^{RUS/UKR} = \beta_0 + \beta_1 P_t^{US/EU/CAN} + \varepsilon_t, \qquad (4)$$

where $P_t^{RUS/UKR}$, $P_t^{US/EU/CAN}$ are prices of Russian, Ukrainian and US, French (EU), and Canadian wheat respectively. β_0 accounts for the transfer costs, β_1 stands for the price transmission elasticity (since our series are expressed in logs), and ε_t is the error term.

Second, we test whether $\gamma = 0$ (i.e. unit root is present and series is not stationary) in the following regression:

$$\Delta\varepsilon_t = \gamma\varepsilon_{t-1} + \omega_t, \qquad (5)$$

where ω_t is the white noise term, and ε_t is obtained from (2).

Unit-root tests are used for this purpose. As previously stated, the number of lags is selected by minimizing AIC and making sure that the errors are not serially correlated. Rejecting the null would mean that analyzed wheat prices are cointegrated, i.e. they converge in the long-run. To test for the autocorrelation of the residuals the Durbin-Watson and Breusch-Godfreys tests were used.

If series are not cointegrated, then results of the OLS used to analyze them are biased. If, however, two series are cointegrated, then the OLS estimators are super consistent, which implies that they converge at a faster than normal rate (Listorti, 2008), and they can be used to characterize the series' behavior.

Error- Correction Model

When two price series are cointegrated, their short-run dynamics can be analyzed by using an error correction model (example of Russia and the U.S.) of the following form (Keele, 2004):

$$\Delta P_t^{RUS} = \alpha_0 - \alpha_1(P_{t-1}^{RUS} - \beta_0 - \beta_1 P_{t-1}^{USA}) + \delta_0 \Delta P_t^{USA} + \varepsilon_t\,, \qquad (6)$$

where $\Delta P_t^{RUS}$and ΔP_t^{USA} are first-differences in log prices for Russia and the US,

P_{t-1}^{RUS} and P_{t-1}^{USA} are lagged log prices of Russia and the US,

δ_0 – captures the immediate effect of the change in the US price on the Russia price (in the literature it is referred to as an initial adjustment term, short-run effect, or contemporaneous effect (Baffes, 2003)),

α_1 – is the speed of adjustment, it indicates how much of the remaining difference in price (1-δ_0) between Russia and the US is eliminated in each next period (it is also referred to as the error-correction term, or feedback effect (Baffes, 2003). Its sign is expected to be negative. It shows that the Russian wheat price in the current period can be explained by the error term from the previous period,

$\beta_0$and β_1- see equation (4), and ε_t is an error term.

Equation 6 can contain more lags of the Russia and the US price differences to deal with the autocorrelation of the error term. The appropriate lag length was selected by using the AIC criterion. Similar equations were estimated for the other analyzed pairs of series as well.

If δ_0 is statistically significant, it means that when the shock occurs in the long-run relationship among the wheat prices of the US, Canada, or EU, part of it is immediately transmitted to the Russian/Ukrainian wheat price, while the rest of the change takes place over some time period. The speed of such an adjustment is captured in α_1.

Empirical Results

We started with determining the order of integration of the analyzed series. The results of the unit-root tests are provided in Table 2.

Table 2. Results of the unit root tests

	# of lags	ADF		PP		KPSS	
		w/ drift	w/ drift and trend	w/ drift	w/ drift and trend	in levels	w/ trend
Ukraine	5	-1.84	-1.95	-1.66	-1.58	1.05**	0.57**
Russia	6	-2.07	-2.21	-1.58	-1.47	1.15**	0.57**
France	5	-1.86	-2.39	-1.34	-1.66	1.32**	0.62**
US	2	-1.61	-1.95	-1.48	-1.85	1.39**	0.52**
Canada	3	-1.55	-1.88	-1.57	-1.82	1.73**	0.51**

Asterisks denote levels of significance (* for 10 percent , ** for 5 percent). The 5% and 10% critical values for the ADF and PP tests with a drift are -2.90 and -2.59 respectively; for the tests with a drift and a trend are -3.47 and -3.16 respectively. Critical values were obtained from MacKinnon (1991). The 5% and 10% critical values for the KPSS test in levels are 0.463 and 0.347 respectively; for the KPSS tests with a trend they are 0.146 and 0.119 respectively.

The tests were run for the cases when trend is present, and when it is absent. The results suggest that including the trend does not affect the outcome, which supports our previous conclusion that there is no significant trend in the series.

As we see from the results of the ADF and PP tests, we fail to reject the null hypothesis that series are non-stationary. KPSS test results also support the evidence of the unit-root presence. Thus, the tests were re-run on the series first differenced in the log levels. The results provided in table 3 show that all the differenced series are stationary. This leads to the conclusion that the price series of Russia, Ukraine, US, Canada and EU are integrated of order 1, i.e. I(1).

Table 3. Results of the unit root tests using first difference

	# of lags	ADF		PP		KPSS	
		w/ drift	w/ drift and trend	w/ drift	w/ drift and trend	in levels	w/ trend
Ukraine	3	-3.02**	-2.97*	-4.73**	-4.68**	0.17	0.115
Russia	2	-3.61**	-3.53**	-4.81**	-4.77**	0.16	0.10
France	2	-4.36**	-4.32**	-5.15**	-5.12**	0.16	0.1203*
US	1	-5.31**	-5.27**	-6.08**	-6.04**	0.10	0.08
Canada	2	-4.17**	-4.13**	-6.83**	-6.79**	0.17	0.10

Asterisks denote levels of significance (* for 10 percent , ** for 5 percent). The 5% and 10% critical values for ADF and PP tests with a drift are -2.90 and -2.59 respectively; for the tests with a drift and a trend are -3.47 and -3.16 respectively. Critical values were obtained from MacKinnon (1991). The 5% and 10% critical values for the KPSS test in levels are 0.463 and 0.347 respectively; for the KPSS tests with a trend they are 0.146 and 0.119 respectively.

The ADF test results for the Ukrainian price series allows us to reject the null only at 10 percent level of significance. However, since in the case of the Philips-Perron test results, we reject the null even at 1 percent level, we conclude that Ukrainian wheat price series are I(1). Also, the KPSS test results for the French series in the case with the included trend seem to be on the border of 10 percent statistical significance. However, since both PP and ADF test strongly suggest that the presence of the trend does not affect the results of the unit root tests, we conclude that there is no significant trend in the French differenced series.

Concluding that the analyzed series are of the same I(1) order allows proceeding to the cointegration tests. We start with the Johansen ML test on all the series of interest to test for the total number of the long-run cointegrating relationships. In order to do so, the appropriate order of VAR is first established for each series. For this purpose partial canonical matrices are used. French, Ukrainian and Russian series turned out to be VAR(2), while U.S. and Canadian ones were VAR(1). Then the actual Johansen ML test was run with 2 lags in the restricted constant form.

The results that are provided in Table 4 suggest that we reject the null hypothesis of no cointegration, i.e. r=0. We also reject H_0 that there is only one cointegrating relationship (r=1). Since, however, we fail to reject the null hypothesis that r=2, we conclude that there are two distinct long-run relationships among the four series.

Table 4. Cointegration rank test using trace

Ho(Rank=r)	H1(Rank>r)	Trace	5% CV
0	0	112.77**	75.74
1	1	62.91**	53.42
2	2	30.57	34.8
3	3	13.4	19.99
4	4	5.38	9.13

Asterisks denote levels of significance (* for 10 percent, ** for 5 percent).

In order to find out what pairs of series are, actually integrated both Johansen's ML and Engel and Granger cointegration tests were run on the pairs of series. The Johansen ML pairwise tests (Table 5) show that the pairs that are cointegrated are Russia-France, Ukraine-France and USA-Canada.

The significance of the French-Ukrainian relationship under the Johansen ML method suggests that one of the cointegration relationships that were established in Table 4 may involve three series – Russia, Ukraine and France. However, since none of the unit-root tests confirmed cointegration between Ukraine and France, we would conclude that these series are not cointegrated, unless further tests prove this wrong.

The Engel and Granger procedure results confirm the long-run relationship between Russia and France, but do not confirm USA-Canada relationship. The difference in the outcomes might be attributed to the different sets of the assumptions that are used when constructing both tests. However, since our interest in this paper is the cointegrating relationship of the Russian and Ukrainian price series, we will not get into further details on the Canada-US pair. There are a number of studies that analyze the latter relationship (Ghoshray, 2007; Goodwin et al., 1991; Barassi et al., 2007; Baek et al., 2006).

Table 5. Pairwise cointegration tests for the wheat price series of interest

Pairs of series	Engel and Granger procedure			Johansen method		
	# of lags for unit-root tests	ADF	PP	Ho(H1)	Trace	5%CV
Russia-France	7	-3.56**	-4.83**	r=0((r>0)	35.59**	19.99
				r=1(r>1)	3.68	9.13
Russia-Canada	12	-2.52	-2.46	r=0((r>0)	14.5	19.99
				r=1(r>1)	4.57	9.13
Russia-USA	7	-2.19	-3.54**	r=0((r>0)	14.89	19.99
				r=1(r>1)	3.35	9.13
USA-Canada	12	-2.73	-2.57	r=0((r>0)	20.87**	19.99
				r=1(r>1)	3.29	9.13
France-USA	12	-1.21	-3.01	r=0((r>0)	12.16	19.99
				r=1(r>1)	3.08	9.13
France-Canada	3	-2.26	-2.42	r=0((r>0)	15.89	19.99
				r=1(r>1)	2.72	9.13
Ukraine-France	7	-2.11	-3.03	r=0((r>0)	20.33**	19.99
				r=1(r>1)	8.58	9.13
Ukraine - Russia	10	-2.11	-2.39	r=0((r>0)	13.48	19.99
				r=1(r>1)	2.98	9.13
Ukraine-USA	1	-2.8	-2.83	r=0((r>0)	12.67	19.99
				r=1(r>1)	4.09	9.13
Ukraine - Canada	12	-2.66	-2.14	r=0((r>0)	13.84	19.99
				r=1(r>1)	5.08	9.13

Asterisks denote levels of significance (* for 10 percent, ** for 5 percent). The 5% and 10% critical values for tests with a drift are -3.42 and -3.10 respectively. Critical values were obtained from MacKinnon (1991).

Philips-Perron test results suggest that Russian wheat prices are cointegrated with the U.S. ones; however, since both ADF and Johansen ML test do not support these results, we conclude that these series are not cointegrated. Overall, we conclude that only Russian and French wheat prices have a statistically significant long-run relationship. Therefore, we can proceed with constructing an error-correction model for these series to analyze the short term dynamics between them. Additionally, since the Russian and French series are cointegrated, the results of the regressions that analyze the relationships between them are consistent. Thus, β_1 can be considered as the long-run price transmission elasticity (see equation 4). The results estimate that the long-run price elasticity between Russia and France is equal to 1.07.

The price transmission elasticity indicates the percentage change in the price of one country in response to a one-percent change in the world market. It is directly related to trade liberalization (Listorti, 2008; Thompson, 1999), since higher levels of trade liberalization contribute to greater price transmission elasticities.

The results of the error correction model (table 6) can be interpreted in the following way - as the French wheat price increases by 1 dollar, the Russian price immediately responds with an increase of 70 cents.

Table 6. Error-correction model parameter estimates

	Immediate effect, δ_0	Speed of adjustment, α_1	Test F-value
Russia-France	0.70**	-0.57**	60.59**

Asterisks denote levels of significance (* for 10 percent, ** for 5 percent).

The speed of the adjustment is equal to 0.57. It shows how long it takes to absorb the remaining price change (100-70 = 30 cents). For example, 57% of the remaining price change or 0.30*0.57 = 0.17 will be absorbed in the first month. In the next month (0.30-0.17)*0.57 = 0.07 (or 7 cents) will be absorbed and so on. The full adjustment is therefore expected to be complete within 6 months. This is considered to be a rapid convergence rate.

Conclusions and Implications

The article investigates the short- and long-run dynamics between Black Sea Region soft and feed wheat and the US, Canadian, and EU wheat prices using monthly FOB data from July 2004 to October 2010. The empirical results suggest that Black Sea soft wheat prices are cointegrated with EU (French) wheat prices, but not with those of the US or Canada. This lets us conclude that the weaker version of the LOP does hold for the Black Sea soft wheat market. The estimated long-run price transmission elasticity between Russia, which represents the Black Sea soft wheat market and France is equal to 1.07.

The short-run relationships between Russian and French series of interest were also found to be statistically significant. The error correction model results show that after the price change occurs in the French price, Russian wheat price adjusts to the change within 6 months.

Ukrainian wheat price series are found to be not cointegrated with the U.S. or Canadian series. This result is different from the older study in 2003, which showed that there was a statistically significant long-run relationship between Ukrainian and U.S. wheat prices. This could suggest the need to extend the analysis by applying the method of the structural breaks. According to Baek et al., if there is a break in the price series, the results of the unit-root tests might be misleading. Therefore, testing for the presence of the structural break in the Ukrainian series will be the next step of the research.

Finally, this study assumed that the Black Sea wheat price adjustment to the shocks that occur to other series is symmetric. This means that whether the shock is positive or negative the response of the Black Sea region prices will be of the same magnitude and speed. However, several studies (Sagidova, 2004; Ghoshray, 2008), suggest that sometimes the adjustment might be asymmetric. To check for asymmetries in the short-run adjustment of Russian wheat prices to those of the EU would be another area of future research. The TAR or M-TAR model is appropriate for this purpose (Ghoshray, 2008; Listorti, 2008; Meyer et al., 2004).

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