International Wheat Trade and Spatial Market Integration in the Black Sea Region

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INTRODUCTION

Figure 1. Wheat Trade Linkages in the Black Sea Region

- Spatial market analysis can be described three categories based on the type of data used. First, the method only uses price data.
- Second, the studies rely on price and transaction costs data, and third, some studies use prices, transaction costs, and trade volumes (Barrett, 1996).
- Actually, spatial price relationships can defined by price, trade volume (or both), and transaction cost (Barrett and Li, 2002).
- This study employs a spatial price analysis approach based on maximum likelihood estimation of a mixture distribution model including price and trade flow data.
- This approach allows for distinguishing between market integration and competitive market equilibrium, as well as deriving intuitive indicators for intermarket tradability, competitive market equilibrium, perfect integration, segmented equilibrium, and segmented disequilibrium.
- An application to trade in wheat markets among Türkiye, Russia, Ukraine, and Kazakhstan.
- The issue of whether the Black Sea Grain Corridor Agreement between Russia and Türkiye will be reinstated or not is being closely monitored by the global public opinion due to its direct impact on global food security.
- Our study adds to the existing body of literature as follows: Firstly, the study based on Barrett and Li (2002), the approach leads to significantly different conclusions compared to traditional market integration testing methods, providing a deeper understanding of potential inefficiencies in trading patterns.
- Secondly, the method allows distinction between *market integration* which reflects the tradability of products between spatially dictinct markets and *competitive market equilibrium*, extraordinary profits are exhausted due to competitive pressures.
- Besides, this study contributes to the literature that the role of Russia, Ukraine, Kazakhstan, and Türkiye in future global food security.

OBJECTIVES

- The primary objective of this study is to evaluate the degree of market integration and the dynamics of competitive market equilibrium between Türkiye and the Black Sea wheat exporters, namely Russia, Ukraine, and Kazakhstan.
- Leveraging the theoretical underpinnings of Barrett's (1996) model, this research aims to discover the extent to which transaction costs and discontinuous trade flows affect market efficiency.
- To our knowledge, this study is the first analysis of wheat market integration between Türkiye and its Black Sea neighbors, providing an empirical perspective on a region critical to global wheat supply.
- In addition, by employing Barrett and Li's (2002) augmented switching regime model, this study diverges from traditional spatial price analyses to reveal a more complex picture of market behaviors and trade inefficiencies.
- This approach allows for distinguishing between market integration and competitive market equilibrium, as well as deriving intuitive indicators for intermarket tradability, competitive market equilibrium, perfect integration, segmented equilibrium, and segmented disequilibrium.
- Additionally, an understanding will be gained about how resilient the regional countries are to potential disruptive price shocks.
- Finally, the study improves our understanding of the role that Russia, Ukraine, Kazakhstan, and Türkiye play for the future global food security.

METHOD and DATA

- The study builds on the basic point that market integration does not equate to competitive spatial equilibrium (Barrett, 1996; Fackler and Goodwin, 2001; Barrett and Li, 2002).

$$P_{it} \leq \tau_{jit}(P_{it}, P_{jt}, c_{jit}) + P_{jt} \quad (1)$$

- Transaction costs can consist of insurance fees, tax payments, storage, marketing and distribution expenditures, intermediaries profits, and transportation costs, c_{jit}. Spatial equilibrium conditions based on the Law of One Price (LOP) will be held with equality, $R_{jit} \equiv P_{it} - P_{jt} - \tau_{jit}$.

$$\text{Perfect integration: } R_{jit} = 0 \text{ and } T_{jit} \geq 0 \quad (2)$$

$$\text{Segmented equilibrium: } R_{jit} < 0 \text{ and } T_{jit} = 0 \quad (3)$$

$$\text{Imperfect integration: } R_{jit} \neq 0 \text{ and } T_{jit} > 0 \quad (4)$$

$$\text{Segmented disequilibrium: } R_{jit} > 0 \text{ and } T_{jit} = 0 \quad (5)$$

Table 1. The Probabilities of Six Regimes

	$P_i - P_j - T_{ji} \equiv R_{ji} = 0$	$P_i - P_j - T_{ji} \equiv R_{ji} > 0$	$P_i - P_j - T_{ji} \equiv R_{ji} < 0$
Trade	λ_1	λ_3	λ_5
No trade	λ_2	λ_4	λ_6

- Regime 1 and 2 imply perfect market integration, that is, reflect tradability in Table 1. Since $R_{ji} > 0$ in the regimes 3 and 4, showing the presence of positive profits to intermarket arbitrage. Regime 3 embodies a particular type of perfect integration, in which trade yields positive marginal profits. Conversely, regime 4 signifies segmented disequilibrium, in which profitable arbitrage opportunities go unrealized. Regime 5 and 6 ($R_{jit} < 0$) represent imperfect integration including negative marginal profits to arbitrage and segmented equilibrium respectively.
- Perfect integration is achieved with probability ($\lambda_1 + \lambda_2$), segmented equilibrium arises with a probability of (λ_6), imperfect integration occurs with a probability of ($\lambda_3 + \lambda_5$), and segmented disequilibrium occurs with a probability of (λ_4) (Barrett and Li, 2002).
- As far as Equations (6)-(10) are concerned, there is a high probability of encountering measurement and sampling errors when working with any data that this model could be examined. In the scenario where perfect integration is assumed as the null hypothesis, there should ideally be no approximation error. Therefore, the only deviations from the equilibrium condition should be attributed to independent and identically distributed (i.i.d.) normal sampling and measurement errors, represented as u_{it}, characterized by a mean of γ a variance of σ_u^2.

$$R_{it} = \begin{cases} \epsilon_{it} + u_{it}, & if \; R_{it} > 0 \; (regimes\ 3\ ve\ 4) \\ \epsilon_{it}, & if \; R_{it} = 0 \; (regimes\ 1\ ve\ 2) \\ \epsilon_{it} - u_{it}, & if \; R_{it} < 0 \; (regimes\ 5\ ve\ 6) \end{cases} \quad (6)$$

where u_{it} is one-sided, positive half-normal error which is independent of ϵ_{it} and its variance σ_u^2.

$$f_{1t} = f_{2t} = \frac{1}{\sigma_\epsilon}\phi\left(\frac{R_t-\gamma}{\sigma_\epsilon}\right) \quad (7)$$

$$f_{3t} = f_{4t} = \left(\frac{2}{\sqrt{\sigma_u^2+\sigma_\epsilon^2}}\right)\phi\left(\frac{R_t-\gamma}{\sqrt{\sigma_u^2+\sigma_\epsilon^2}}\right)\left(1-\Phi\left(\frac{-(R_t-\gamma)\sigma_u/\sigma_\epsilon}{\sqrt{\sigma_u^2+\sigma_\epsilon^2}}\right)\right) \quad (8)$$

$$f_{5t} = f_{6t} = \left(\frac{2}{\sqrt{\sigma_u^2+\sigma_\epsilon^2}}\right)\phi\left(\frac{R_t-\gamma}{\sqrt{\sigma_u^2+\sigma_\epsilon^2}}\right)\left(1-\Phi\left(\frac{(R_t-\gamma)\sigma_u/\sigma_\epsilon}{\sqrt{\sigma_u^2+\sigma_\epsilon^2}}\right)\right) \quad (9)$$

where ϕ is the standard normal density function and Φ is the standard normal cumulative distribution function. Consequently, the likelihood of observing the sample data $\{R_{jit}, T_{jit}\}$ is thus:

$$L = \prod_{t=1}^{T}(A_{it}.[\lambda_1 f_{1t} + \lambda_3 f_{3t} + \lambda_5 f_{5t}] + (1-A_{it})[\lambda_2 f_{2t} + \lambda_4 f_{4t} + \lambda_6 f_{6t}]) \quad (10)$$

where A_{it} is a binary indicator variable with a value of one indicating the presence of trade and zero indicating its absence. The probabilities of λ_k defining the six regimes, transaction cost γ, and the error parameters σ_u and σ_v's estimations can be achieved by maximizing the logarithm of equation (10), subject to the constraints that $\lambda_k \geq 0 \; \forall k$ and $\sum_k \lambda_k$.

- Specifically, utilizing the time-invariant estimates of parameters $\lambda, \gamma, \sigma_u$, and σ_v, along with information on trade volumes ($A_{it} = 0 \; or \; 1$), enables the derivation of semiparametric estimates for time-varying regime probabilities.
- Our dataset includes monthly observed wheat prices and trade flows in Türkiye spanning from January 1994 to December 2022, derived from the Turkish Statistical Institute (TurkStat) database of agricultural product prices. The timeframe was selected based on the extent of data availability within TurkStat's records. Additionally, we sourced monthly Free On Board (FOB) wheat prices for Russia and Ukraine from the APK-Inform agency. Delivered at Place (DAP) wheat prices for Kazakhstan was also collected from the APK-Inform agency. We collected trade volume data from TurkStat and United Nations Comtrade Database.
- The respective data coverage for each country is as follows: Russia from October 2006 to December 2023, Ukraine from January 2000 to December 2023, and Kazakhstan from June 2011 to December 2023. Figure 2 illustrates the wheat prices in international markets in U.S. dollars per kilogram ($/kg). As expected, the prices in Black Sea region are consistently lower than wheat prices in Türkiye. The vertical line showing the date February 2022 represents the war that started in Ukraine. The other vertical line in Figure 2 represents The Black Sea Grain Initiative, which was signed in July 2022. As can be seen in Figure 3, Black Sea regions have experienced price increases following the war in Ukraine.

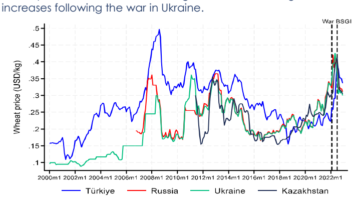


Figure 2. Wheat Prices in the Black Sea Region

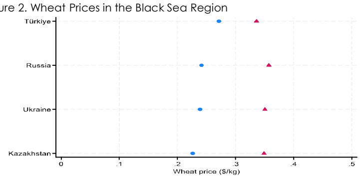


Figure 3. Sample Means (Blue dot: Pre-war average; red triangle: Post-war average)

RESULTS

Switching Regime Estimation Results

Table 2. Estimated Regime Probabilities for Full Sample

Countries From	To	Trade λ_1	λ_3	λ_5	No Trade λ_2	λ_4	λ_6	Costs γ_0	Stan. dev. σ_ϵ	σ_u	N
Rus	Tur	0.18	0.00	0.52***	0.00	0.28***	0.02	0.07***	0.03**	0.07***	195
		(0.23)	(0.26)	(0.21)	(0.08)	(0.09)	(0.02)	(0.02)	(0.01)	(0.01)	
Tur	Rus	0.00	0.05	0.03	0.00	0.00	0.91	0.00	0.05**	0.07**	195
		(0.10)	(0.10)	(0.04)	(1.16)	(0.05)	(1.18)	(0.09)	(0.02)	(0.03)	
Ukr	Tur	0.17*	0.05*	0.28**	0.06	0.44***	0.00	0.06***	0.03***	0.07***	276
		(0.12)	(0.03)	(0.13)	(0.10)	(0.13)	(0.09)	(0.01)	(0.009)	(0.007)	
Tur	Ukr	0.00	0.01	0.02	0.00	0.03	0.94	0.00	0.04*	0.09	276
		(0.03)	(0.02)	(0.05)	(2.14)	(0.12)	(2.28)	(0.21)	(0.03)	(0.06)	
Kaz	Tur	0.00	0.56***	0.34***	0.00	0.02	0.08**	0.04***	0.01	0.06***	139
		(0.08)	(0.14)	(0.10)	(0.02)	(0.01)	(0.03)	(0.01)	(0.03)	(0.008)	
Tur	Kaz	0.02	0.00	0.02	0.00	0.00	0.96	0.02	0.04*	0.08***	139
		(0.05)	(0.11)	(0.05)	(1.56)	(0.14)	(1.59)	(0.13)	(0.03)	(0.02)	
Rus	Ukr	0.07**	0.00	0.01	0.59***	0.06**	0.28***	0.00	0.01***	0.05***	207
		(0.03)	(0.00)	(0.007)	(0.07)	(0.02)	(0.05)	(0.00)	(0.00))	(0.004)	
Ukr	Rus	0.06**	0.05	0.01*	0.65***	0.20***	0.06***	0.003***	0.004***	0.05***	207
		(0.02)	(0.06)	(0.009)	(0.06)	(0.04)	(0.02)	(0.00)	(0.00)	(0.006)	
Rus	Kaz	0.14	0.00	0.51	0.18	0.02	0.15	0.00	0.03*	0.02	151
		(1.55)	(0.00)	(1.40)	(0.61)	(0.23)	(0.65)	(0.00)	(0.02)	(0.03)	
Kaz	Rus	0.00	0.17**	0.50***	0.11	0.03	0.19**	0.03**	0.02***	0.04***	151
		(0.00)	(0.08)	(0.16)	(0.09)	(0.04)	(0.11)	(0.01)	(0.006)	(0.007)	
Ukr	Kaz	0.00	0.00	0.04	0.16	0.29**	0.51**	0.00	0.01*	0.04***	151
		(46.1)	(500)	(0.04)	(0.20)	(0.15)	(0.27)	(0.01)	(0.008)	(0.004)	
Kaz	Ukr	0.02	0.00	0.00	0.72	0.00	0.25	0.02*	0.03**	0.04**	151
		(110)	(103)	(81)	(0.67)	(0.30)	(0.48)	(0.01)	(0.01)	(0.02)	

Table 3. Estimated Regime Probabilities for Pre-War Period

Countries From	To	Trade λ_1	λ_3	λ_5	No Trade λ_2	λ_4	λ_6	Costs γ_0	Stan. dev. σ_ϵ	σ_u	N
Rus	Tur	0.14	0.00	0.55**	0.00	0.28**	0.03	0.08***	0.02*	0.07***	184
		(0.27)	(0.28)	(0.24)	(0.10)	(0.10)	(0.03)	(0.02)	(0.02)	(0.008)	
Tur	Rus	0.00	0.03	0.02	0.00	0.00	0.95	0.00	0.05	0.08	184
		(0.15)	(0.16)	(0.04)	(3.96)	(0.33)	(4.09)	(0.32)	(0.05)	(0.09)	
Ukr	Tur	0.14	0.04	0.29*	0.07	0.46**	0.00	0.06**	0.03**	0.06***	265
		(0.19)	(0.04)	(0.20)	(0.17)	(0.22)	(0.12)	(0.02)	(0.01)	(0.01)	
Tur	Ukr	0.00	0.01	0.01	0.00	0.00	0.98	0.00	0.05*	0.09	265
		(0.02)	(0.02)	(0.04)	(3.31)	(0.05)	(3.35)	(0.30)	(0.03)	(0.09)	
Kaz	Tur	0.00	0.56***	0.34***	0.00	0.02	0.08**	0.04***	0.01	0.05***	128
		(0.08)	(0.13)	(0.11)	(0.03)	(0.01)	(0.03)	(0.01)	(0.03)	(0.01)	
Tur	Kaz	0.02	0.004	0.01	0.00	0.00	0.96	0.00	0.05	0.06	128
		(0.07)	(0.13)	(0.10)	(3.75)	(0.38)	(3.88)	(0.21)	(0.05)	(0.07)	
Rus	Ukr	0.07**	0.00	0.01	0.61***	0.06**	0.25***	0.00	0.004***	0.05***	184
		(0.04)	(0.34)	(0.008)	(0.08)	(0.02)	(0.04)	(0.001)	(0.00)	(0.005)	
Ukr	Rus	0.07**	0.01	0.01*	0.68***	0.17***	0.05**	0.0028***	0.004***	0.06***	184
		(0.02)	(0.01)	(0.009)	(0.06)	(0.04)	(0.02)	(0.00)	(0.00)	(0.008)	
Rus	Kaz	0.00	0.03	0.68	0.09	0.00	0.20	0.00	0.03	0.02	128
		(5.73)	(0.78)	(6.30)	(1.68)	(0.93)	(2.28)	(0.19)	(0.04)	(0.10)	
Kaz	Rus	0.00	0.17	0.52	0.12	0.00	0.19	0.03	0.02	0.03***	128
		(0.27)	(0.22)	(0.46)	(0.19)	(0.37)	(0.18)	(0.03)	(0.02)	(0.01)	
Ukr	Kaz	0.00	0.00	0.05	0.60	0.04	0.36	0.00	0.03	0.03	128
		(3.17)	(8.61)	(0.33)	(2.62)	(0.52)	(2.22)	(0.04)	(0.02)	(0.06)	
Kaz	Ukr	0.02	0.00	0.00	0.01	0.44**	0.52**	0.013***	0.001	0.03***	128
		(0.14)	(2.29)	(2.01)	(0.02)	(0.06)	(0.07)	(0.001)	(0.002)	(0.003)	

Significance levels: ***1%, **5%, *10%. Asymptotic standard errors are in parantheses

- Table 2, 3 and 4 present switching regime estimation results, which illustrate full sample and pre-war periods respectively.
- Involving Russia, Ukraine, and Kazakhstan, imperfect integration manifests with statistically significant frequency the series.
- The considerable λ_5 estimates concerning flows from Russia to Türkiye, from Ukraine to Türkiye, and from Kazakhstan to Türkiye are probably a result of aggregation bias from trade flow data and imperfectly comparable price series.
- The quite large (0.56) and statistically significant λ_3 estimates for trade flows Kazakhstan to Türkiye indicate positive marginal rents to arbitrage into the market of Türkiye.
- Segmented disequilibrium (λ_4), where positive expected profits to arbitrage are not fully utilized, is common between Türkiye and the Black Sea exporting countries.
- The estimated λ_4 is statistically significant, at 0.28 for the trade from Russia to Türkiye. In trade from Ukraine to Türkiye, it was 0.46 before the war in Ukraine, whereas in the estimation made with the full sample, it dropped to 0.44.

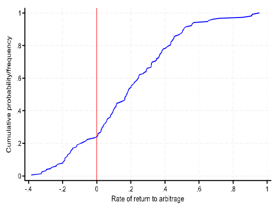
- In the wheat trade between Ukraine and Russia, while the transaction costs estimated at 0.28 cents per kg before the war, are estimated at 0.3 cents in the full sample. Similarly, transaction costs in Kazakhstan-Ukraine trade have also risen with the onset of the war.
- In estimated transaction costs related to trade between Ukraine-Türkiye and Kazakhstan-Türkiye, there is no significant difference.
- The tradable relationship between Türkiye, which imports wheat, and its foreign trade partners is effective.
- Moreover, although the probability of perfect integration is low, the probability of imperfect integration decreased from 55% before the war to 52% with the onset of the war (from Russia to Türkiye).
- The Russia-Türkiye relationship is tradable at 70% probability and it is at a similar level before the war as well.
- As a consequence of intra-industry trade, the estimated market equilibrium probability for wheat exported from Türkiye to Russia has decreased with the war in Ukraine.
- The intermarket tradability probabilities for Ukraine-Türkiye and Kazakhstan-Türkiye are 56% and 90% respectively.
- Thus, wheat is effectively tradable between Türkiye and Black Sea exporting countries.

Table 4. Regime Probability Estimates of Intermarket Conditions

From/to	Perfect integration	Segmented equilibrium	Imperfect integration	Segmented disequilibrium	Market equilibrium	Intermarket tradability
	$\lambda_1 + \lambda_2$	λ_6	$\lambda_3 + \lambda_5$	λ_4	$\lambda_1 + \lambda_2 + \lambda_6$	$\lambda_1 + \lambda_2 + \lambda_3 + \lambda_5$
Full Sample						
Rus-Tur	0.18	0.02	0.52	0.28	0.20	0.70
Tur- Rus	0.00	0.91	0.08	0.00	0.91	0.08
Ukr-Tur	0.23	0.00	0.33	0.44	0.23	0.56
Tur- Ukr	0.00	0.94	0.03	0.03	0.94	0.03
Kaz-Tur	0.00	0.08	0.90	0.02	0.08	0.90
Tur- Kaz	0.02	0.96	0.02	0.00	0.98	0.04
Rus-Ukr	0.66	0.28	0.01	0.06	0.94	0.67
Ukr-Rus	0.71	0.06	0.06	0.20	0.77	0.77
Rus-Kaz	0.32	0.15	0.51	0.02	0.47	0.83
Kaz-Rus	0.11	0.19	0.67	0.03	0.30	0.78
Ukr-Kaz	0.16	0.51	0.04	0.29	0.67	0.20
Kaz-Ukr	0.74	0.25	0.00	0.00	0.99	0.74
Pre-war						
Rus-Tur	0.14	0.03	0.55	0.28	0.17	0.69
Tur- Rus	0.00	0.95	0.05	0.00	0.95	0.05
Ukr-Tur	0.21	0.00	0.33	0.46	0.21	0.54
Tur- Ukr	0.00	0.98	0.02	0.00	0.98	0.02
Kaz-Tur	0.00	0.08	0.90	0.02	0.08	0.90
Tur- Kaz	0.02	0.96	0.02	0.00	0.98	0.04
Rus-Ukr	0.68	0.25	0.01	0.06	0.93	0.69
Ukr-Rus	0.75	0.05	0.02	0.17	0.80	0.77
Rus-Kaz	0.09	0.20	0.71	0.00	0.03	0.80
Kaz-Rus	0.12	0.19	0.69	0.00	0.31	0.81
Ukr-Kaz	0.60	0.36	0.05	0.04	0.96	0.65
Kaz-Ukr	0.03	0.52	0.00	0.44	0.55	0.03

- With the war, the possibilities for integration (and intermarket tradability) between Russia and Ukraine have decreased.

A Supportive Nonparametric View



- Figures 4 illustrates the example of plotting the cumulative frequency distribution of the percent returns to arbitrage ($r_{jit} \equiv \frac{R_{jit}}{P_{jt}}$), for the cases of trade from Russia to Türkiye with trade.
- As seen in Figure 4, returns are clustered close to zero in the case of Russia to Türkiye trade, with roughly 25% of observations.
- The simple data plot aligns with the results of the previously introduced parametric method.
- The results indicate that the markets do not reflect competitive equilibrium, but rather exhibit imperfect integration, especially with the feature of intermarket tradability.

Figure 4. Russia to Türkiye arbitrage rents period with trade

CONCLUSIONS

- This article attempts to connect price-based and quantity-based approaches in studying spatial market integration.
- It employs the methodology of Barrett and Li (2002) that utilizes ML estimation of a mixture distribution model, which incorporates price and trade flow data.
- We demonstrate how this novel approach enables the direct estimation of the likelihood that the relationship between two markets falls into one of four fundamental conditions: perfect integration, segmented equilibrium, imperfect integration, or segmented disequilibrium, as derived from theory.
- Additionally, information has been acquired regarding how the war has changed market conditions over time.
- According to the estimation results, the war has significant impact on transaction costs (Ukraine-Russia and Kazakhstan-Ukraine). However, market pairs where this effect does not arise due to observation inadequacy, such as Russia-Türkiye, are also present.
- Parametric method estimates indicate that imperfect integration, especially with the feature of intermarket tradability prevails.
- Both parametric and nonparametric method estimates indicate that markets are deviating from the competitive market equilibrium.
- One of the reasons for the high level of imperfect integration is the unpredictable policies that Russia applies to wheat markets (tax, export restrictions, etc.).
- Implementing measures to reduce trade barriers such as unpredictable taxes, quotas, and non-tariff barriers observed in Black Sea countries can help enhance market integration by promoting smoother flows of goods across borders.

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