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Horizontal Price Transmission on the Russian Dairy Market: Nonlinear Approach

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Abstract

Spatial (horizontal) price transmission analysis provides specific evidence as to the competitiveness of markets, the effectiveness of arbitrage and the pricing efficiency. The paper investigates spatial price transmission and market integration in the Russian Federal Districts using monthly milk prices within the period 2000-2018. Using Hansen-Seo technique, threshold effects have been found and threshold vector error correction model with two regimes has been estimated for three markets. Market integration analysis revealed a long-run relationship for all the price pairs in the milk markets. The linear VECM analysis showed a rather low degree of integration, especially for the Southern Federal District milk market. Compared to VECM, the TVECM estimation provided different findings depending on regimes and markets.

Keywords

Spatial price transmission, market integration, Threshold Vector Error Correction model, milk market, Russia.

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Introduction

The nature of markets and their role in price determination are central to economics. Geographic markets are particularly relevant to agriculture since agricultural products are typically bulky and/or perishable and areas of production and consumption are separated; hence, transportation is costly (Sexton et al., 1991). Market integration characterizes price transmission degree on geographic markets. Price transmission is when a change of prices in one market causes prices in another one to change. Commonly, it is measured in terms of the transmission elasticity, defined as the percentage change in the price in one market given a 1% change in the price in another market.

The market integration measurement and transmission of food price shocks is a major determinant of price stability and food security, particularly in developing countries such as Russia. Russia is aiming at self-sufficiency in milk production. This is part of a broader plan to move Russia away from reliance on imported foodstuffs, and into a net exporter within the next 10 years. In accordance with the doctrine of food security, the share of domestic milk in the Russian market should be 90%. In 2017 it amounted to 80.8 % based on the last data from the Federal State Statistics Service of Russia (available online at http://www.gks.ru). According to the forecast of the Ministry of agriculture, milk production in 2018 will increase by 2% compared to the last year.

Information on spatial price transmission may, therefore, provide specific evidence as to the competitiveness of markets, the effectiveness of arbitrage (it exists as a result of market inefficiencies and would, therefore, not exist if all markets were perfectly efficient), and the efficiency of pricing. However, it may be difficult to recognize the specific cause(s) of observance or failure to observe the law of one price (Sexton et al., 1991). Consequently, it is worth evaluating the degree of market integration on the Russian milk market by means of the latest econometric techniques.

A vast literature on spatial price transmission has been accumulated over the last years. Some researchers (Zakari et al., 2014; Conforti, 2004; Minot, 2011) analyzed the relationship between world and domestic food markets, investigating how world prices are transmitted in domestic food markets. Many authors (Brosig et al., 2011; Habte, 2017; Ganneval, 2016) analyzed spatial price transmission among regions and provinces with regard to food markets. There is some gap in our knowledge concerning horizontal price transmission on Russian milk market that the paper sought to fill.

In the literature, a great deal of econometric techniques are used to measure the integration and price transmission between spatially separated markets. The models that analyze price transmission are based on the regression of differentiated price variables and on lagged price differences. The majority of literature on spatial price transmission relies on co-integration technique and error correction modelling. Huge number of studies (Jena, 2016; Savadatti, 2018; Zhou and Koemle, 2015; Arnade et al., 2017) examined the market integration and horizontal price transmission using the time series techniques of co-integration and linear vector error correction models (VECM). However, analyzing spatial price transmission, researchers often have the lack of information on transaction costs. Linear VECM relies only on price data and does not take into consideration transaction costs.

In order to incorporate effects of transaction costs into price transmission analysis, threshold vector error correction model (TVECM) has been developed. Balke and Fomby (1997) introduced the threshold cointegration approach. Extension to a threshold VECM has been made by several authors (Barrett, 2001; Barrett and Li, 2002; Baulch, 1997; McNew and Fackler 1997; Hansen and Seo, 2002; Seo, 2006). In a TVECM, transaction costs from one market to another market can be estimated by a threshold estimator. Compared to the standard VECM, TVECMs not only show price dynamics between two spatial markets, but also measure the level of spatial price efficiency (Hu and Wade Brorsen, 2017).

Many studies use threshold error correction models to analyze horizontal price transmission. For example, Chen and Saghaian (2016) estimated TVECM for rice price data from Thailand, Vietnam and United States. They found that export prices in the three countries are cointegrated, with Thailand and the United States the price leaders, and that the Vietnamese price adjusts faster to long-run equilibrium when it is above its equilibrium level with Thai and U.S. prices. Wu and Guan (2018) evaluated a threshold vector error correction model allowing for two- layer regime switching with using daily tomato prices for the U.S. and Mexican markets. Their analysis provides evidence that the price floors are effective in influencing spatial price linkages. Models imply much slower adjustments in response to deviations from equilibrium when the price floors are binding. The results confirm that the U.S. and Mexican markets are more tightly integrated when trade is not affected by price floors.

Our study is expected to contribute to the existing literature on spatial price transmission and market integration. The contribution of the paper is twofold. Firstly, it provides a review dealing with the issue of spatial price transmission in the Russian milk market. Secondly, it gives empirical evidence of the extent of market integration in the Russian dairy sector by means of using threshold cointegration approach.

Materials and methods

The horizontal price transmission analysis has been implemented using 224 monthly prices for cow whole milk at the wholesale level from January 2000 to August 2018 in four Russian Federal Districts (Central Federal District, Volga Federal District, Northwestern Federal District and Southern Federal District). The source of the data is the Federal State Statistics Service of Russia (available online at http://www.gks.ru). In order to calculate price elasticities and mitigate fluctuations of time series, we use the logarithmic transformation of monthly prices measured in Russian rubles per tonne.

Most of the price time series are non-stationary that generally leads to spurious regression and cannot be estimated correctly with OLS method. In order to avoid model misspecification, we tested all the price series for the stationarity. To test the unit root presence, some methodological approaches are available. Widely used among them are the Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1979) and the Phillips-Perron test (Phillips and Perron, 1988). The Phillips-Perron and ADF tests specify the null hypothesis that the price series is non-stationary, i.e. unit root is present. In small samples, the general observation is that the Augmented Dickey-Fuller and Phillips-Perron tests have low power. In our case we have sufficient number of observations, that is desirable. The number of the optimum lags was chosen based on the Akaike (1973) information criterion (AIC). To select the highest number of lags for unit root tests, we applied the rule by Schwert (1989) as follows:

$$P_{max} = 12 \times \sqrt[4]{\frac{T}{100}} \qquad (1)$$

where T is sample size.

There might be a linear combination of nonstationary and same integrated price series that is stationary. Price series tend to move identically over time and have common stochastic trend, i.e. series are cointegrated. In that case we obtain not just consistent OLS-estimates (as in the case of classical regression), but super-consistent estimates for the model parameters. One of the first to introduce the cointegration concept was Granger (1981). The basis of the cointegration framework developed by Engle and Granger (1987). However, in our analysis we applied the Johansen approach based on likelihood ratio tests (Johansen, 1988; Johansen and Joselius, 1990; Johansen, 1991; Johansen, 1995). Compared to Engle-Granger technique there is no need to choose which price variable should be dependent. Moreover, the Johansen procedure is capable of dealing with multivariate system of nonstationary price variables. In order to identify the number of cointegration vectors in the Johansen test, the trace statistic and the maximum eigenvalue are used. The null hypothesis for the trace test is that the number of cointegration vectors is r=r*<k, versus the alternative that r=k. Testing proceeds sequentially for r*=1,2… and the first non-rejection of the null is taken as an estimate of r. The null hypothesis for the maximum eigenvalue test is as for the trace test but the alternative is r=r*+1 and, again, testing proceeds sequentially for r*=1,2… with the first non-rejection used as an estimator for r. If two tests produce different results, we rely on trace statistic since it tends to have superior power in empirical studies (Lutkepohl et al., 2001).

The cointegrated price variables have a Vector Error Correction model (VECM) representation. The VECM takes into account price deviations around the long-run equilibrium. VECM can be defined as follows:

$$\Delta P_t = c + \Pi P_{t-1} + \sum_{i=1}^{k} \Gamma_i \Delta P_{t-i} + \varepsilon_t \tag{2}$$

where c is the constant; P_t is the (2x1) vector of price variables defined in the model (logarithms of the two price pairs); the long-run matrix Π can be decomposed into Π=αβ′, where α is the vector, representing the speed of adjustments of the price variables toward long-run equilibrium and β is the cointegration vector, reflecting the linear relationships among the variables in the long-run equilibrium. ΠP_{t-1} can be rewritten as $\alpha\beta' P_{t-1}$, where $\beta' P_{t-1}$ is also denoted as the error correction term ECT_{t-1}, representing the deviation from the long-run equilibrium at period t-1; the Γ_i is the (2x2) matrix of coefficients for an *i* order lag process that represent temporary effects of price changes in previous periods on current price changes; ε_t is (2x1) vector of i.i.d normal disturbances. The optimum lag length is defined in accordance with the AIC and the Schwarz-Bayesian (1978) information (BIC) criterions as a result of VAR modeling.

For spatial price transmission analysis aforementioned VECM has serious restriction in the aspect of linearity. The linear VECM determines that price pairs adjust to the long-run equilibrium at a constant speed (α). To take into account the presence of no-arbitrage band and model various adjustment speeds to long-run equilibrium, linear VECM is extended to a Threshold VECM (TVECM). In the TVECM framework, adjustments occur once the deviations in the long-run equilibrium have exceeded critical threshold (transaction costs). TVECM belongs to the class of regime-switching models. The model can be specified with a constant, a trend or none. Two-regime TVECM can be defined as follows:

$$\Delta P_t = \begin{cases} \mathrm{c1} + \alpha 1 \mathrm{ECT}_{t-1} + \sum_{i=1}^{k} \Gamma 1_{t-i} \Delta \mathrm{P}_{t-i} + \varepsilon 1_t \,, if\ \mathrm{ECT}_{t-1} \le \gamma \\ \mathrm{c2} + \alpha 2 \mathrm{ECT}_{t-1} + \sum_{i=1}^{k} \Gamma 2_{t-i} \Delta \mathrm{P}_{t-i} + \varepsilon 2_t \,, if\ \mathrm{ECT}_{t-1} > \gamma \end{cases} \tag{3}$$

where γ is threshold parameter for the error correction term ECT_{t-1}. For one threshold and cointegration vector, the model is linear, so estimation of the regression parameters can be done by CLS (Conditional Least Squares). The search of the threshold and cointegrating parameters values which minimize the residual sum of squares (SSR) is made on a grid search. The model estimation was carried out using open-source package "tsDyn" in the econometric software "R" developed by Stigler (2013).

In order to detect the threshold effects, we use the supreme Lagrange Multiplier (SupLM) test with the null hypothesis of linear VECM against the alternative of threshold cointegration developed by Hansen and Seo (2002). The SupLM test statistic can be defined as follows:

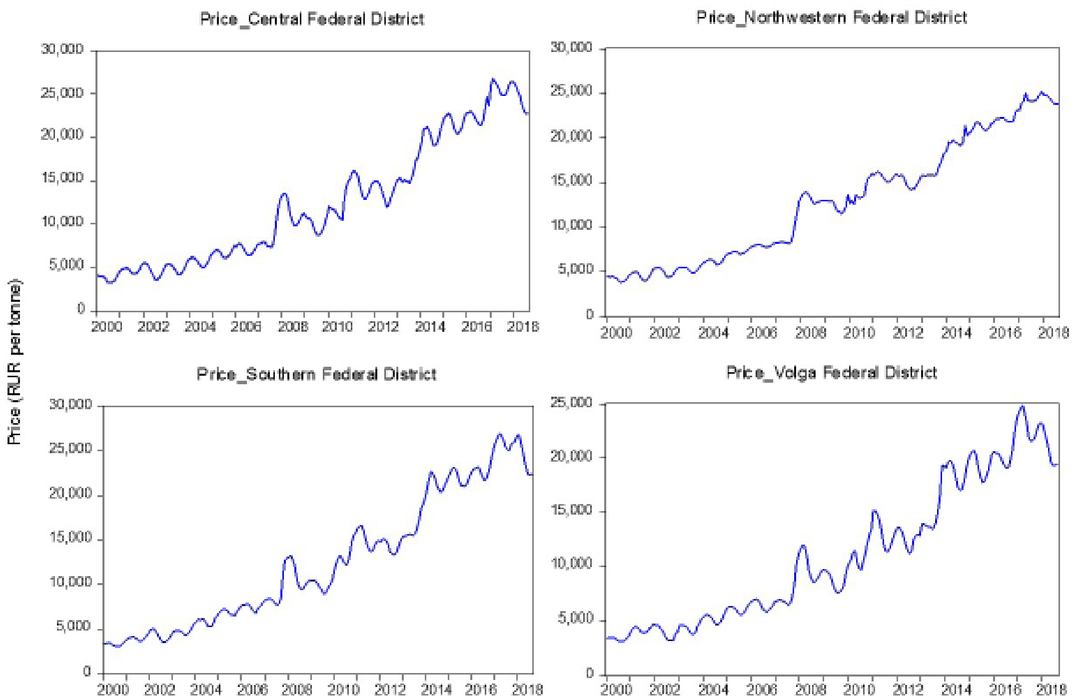
$$SupLM = \sup_{\gamma_L \le \gamma \le \gamma_U} SupLM(\tilde{\beta}, \gamma) \tag{4}$$

where γ is the threshold value; $\tilde{\beta}$ is the estimated cointegration coefficient from linear VECM; γ_L is the trimming parameter (π_0) percentile of ECT_{t-1}, and γ_U is the ($1-\pi_0$) percentile of ECT_{t-1}. The trimming parameter is used to provide a minimum number of observations in each regimes. Andrews (1993) revealed that setting π_0 within the range from 0.05 to 0.15 is typically good choice. We set π_0 equal to 0.1. A grid search within γ_L and γ_U is carried out to obtain γ, which maximizes the SupLM test statistic. To compute asymptotic critical values of the distribution we use 1000 bootstrap replications with two bootstrap approaches (a fixed-regressor and a residual bootstrap).

Results and discussion

The trend and price fluctuations in four Federal districts over the period since 2000 can be observed in the Figure 1. As seen from the figure, prices seem to change synchronously with the common upward tendency within the period under consideration. Hence, there might be co-integration relationships and some kind of price transmission is present. Visual examination of graphs suggests probable price series non-stationarity. Constant should be included in the models for unit root test since times series have a changing mean.

Non-stationarity of the logged price series was identified with the ADF and Phillips-Perron test. We set the maximum lag based on Schwert (1989) rule and used the information criterion AIC to select the optimal lag order. The null hypothesis H0 is rejected if the critical value is greater than the test statistic (p-value is less than level of significance). The findings are presented in the Table 1. The output summarized in the table shows that null hypothesis of non-stationary price series in levels was not rejected for all variables. Tests based on first differences show that all



Source: Federal State Statistics Service of Russia

Figure 1: Price series for raw cow milk in the Russian Federal Districts, January 2000-August 2018.

Logged price variable	Augmented Dickey-Fuller (ADF) test				Phillips-Perron (PP) test			
	Lag	Levels	Lag	1st difference	Bandwidth	Levels	Bandwidth	1st difference
Plog_CFD	14	-0.7936	14	-4.7334***	2	-1.0851	5	-6.5930***
Plog_NFD	14	-0.9655	13	-4.0036***	2	-0.8595	7	-7.7026***
Plog_SoFD	14	-1.2765	14	-4.7233***	2	-1.2597	10	-4.2059***
Plog_VFD	14	-0.8541	14	-4.9189***	3	-1.2610	4	-7.1786***

Note: All models include a constant; */**/*** null hypothesis of non-stationarity rejected at 10%, 5% and 1% of significance
Source: own calculations

Table 1: Unit root test results.

the test statistics are significant at 1% critical level. Therefore, we can infer that all logged price variables are integrated of the order one, I (1). Our findings allow us to run co-integration test between price pairs.

Given that price variables are integrated of the same order, we tested them by Johansen technique in order to find out if the non-stationary series are co-integrated. The optimal lag has been selected based on the information criterions as a result of VAR modeling. The Table 2 presents the results of pair-wise co-integration tests for the all logged price series. The Johansen test revealed one co-integrating equation in all the six price pairs, based on the trace and maximum eigenvalue statistics (the H_0 of r=0 is rejected at the 1 % or 5 % significance level). This implies that the price variables are co-integrated, they have linear long-term relationship during the period and demonstrate common stochastic trend. Hence, we are able to estimate a linear VECM for each price pair.

As seen from the Table 3, linear VEC model reveals that ECT values are statistically significant and negative, indicating adjustment towards equilibrium in the system. The higher ECT value, the faster speed of adjustment to the equilibrium. The Table 3 reveals that the adjustment parameter of Central Federal District (CFD) prices is higher with all other markets (circa 14, 16 and 21 % of prices are adjusted by CFD milk market with three other markets respectively). The CFD market shows the highest adjustment (21 %) with Volga Federal District (VFD) milk prices. That is in line with the fact that VFD and CFD markets are the first and the second one in terms of raw milk production and population number. In the long-term period, a 1 percent of increase

Price Pairs	Hypothesized number of co-integrating equation	Trace statistics	Max- Eigen values	Price Pairs	Hypothesized number of co-integrating equation	Trace statistics	Max- Eigen values
Plog_CFD-Plog_NFD	None (r=0) At most 1 (r≤1)	30.065*** 0.948	29.116*** 0.948	Plog_NFD-Plog_SoFD	None (r=0) At most 1 (r≤1)	17.524** 1.549	15.975** 1.549
Plog_CFD-Plog_SoFD	None (r=0) At most 1 (r≤1)	20.170*** 3.468*	16.702** 3.468*	Plog_NFD-Plog_VFD	None (r=0) At most 1 (r≤1)	18.191** 0.901	17.289** 0.901
Plog_CFD-Plog_VFD	None (r=0) At most 1 (r≤1)	25.626*** 1.744	23.882*** 1.744	Plog_SoFD-Plog_VFD	None (r=0) At most 1 (r≤1)	24.804*** 2.253	22.551*** 2.253

Note: ***/**/* denotes rejection of the null at 1, 5 or 10 % significance level
Source: own calculations

Table 2: Pair-wise Johansen co-integration test for logged price series.

Price Pairs	Co-integrating vector (β) in the long-run	Speed of adjustment	Robustness tests		
			Serial Correlation LM test (p-value)	White's Heteroscedasticity (p-value)	Doornik-Hansen Normality test (p-value)
Plog_CFD-Plog_NFD	1.000-1.034	-0.142*** -0.012	0.0026	0	0
Plog_CFD-Plog_SoFD	1.000-0.929	-0.158*** -0.056*	0.0120	0	0
Plog_CFD-Plog_VFD	1.000-0.993	-0.208*** 0.067	0.0213	0.0046	0
Plog_NFD-Plog_SoFD	1.000-0.907	-0.077*** 0.025	0.0005	0	0
Plog_VFD-Plog_NFD	1.000-1.049	-0.070** 0.038*	0.0001	0	0
Plog_VFD-Plog_SoFD	1.000-0.961	-0.111** 0.003	0.0350	0.019	0

Note: ***/**/* denotes rejection of the null at 1, 5 or 10 % significance level
Source: own calculations

Table 3: Linear VECM results.

in the VFD milk prices leads to 0.99 percent increase in the CFD milk prices, indicating an almost perfect ("one-to-one") price transmission. Meanwhile, there is low degree of integration of the Southern Federal District (SoFD) milk market due to the lack of well-developed transportation and communication infrastructure. We can observe a quiet small adjustment of the SoFD market with the CFD one (5.6 %), which is only significant at 90 per cent. ECT for SoFD market are not significant and just 2.5 and 0.3 percent with Northwestern Federal District (NFD) and Volga Federal District (VFD) respectively. Our VECM is well specified because model residuals do not suffer from serial autocorrelation, there is no heteroscedasticity and the residuals are normally distributed.

The SupLM test rejects the null hypothesis of linear integration, detecting the threshold effects for three out of six price pairs at the 5 % significance level (CFD-NFD, CFD-VFD and VFD-SoFD markets). Due to the Table 4 results, only the linear VECM is estimated for three markets: CFD-SoFD, NFD-SoFD and VFD-NFD.

Table 5 presents the TVECM results for three price

Price Pairs	**Type of bootstrap simulation**	**Cointegrating vector, β**	**Threshold parameter, γ**	**SupLM test statistics**	**Critical Value at 5 % significance**
Plog_CFD-Plog_NFD	Fixed regressor	-1.034	-0.329	20.369** (0.024)	18.989
	Residual bootstrap			20.369** (0.012)	17.347
Plog_CFD-Plog_SoFD	Fixed regressor	-0.929	0.651	23.652 (0.384)	30.34
	Residual bootstrap			23.652 (0.161)	27.711
Plog_CFD-Plog_VFD	Fixed regressor	-0.993	0.159	34.947*** (0.004)	29.209
	Residual bootstrap			34.947*** (0.001)	27.031
Plog_NFD-Plog_SoFD	Fixed regressor	-0.907	0.954	23.935 (0.343)	29.451
	Residual bootstrap			23.935 (0.121)	26.791
Plog_VFD-Plog_NFD	Fixed regressor	-1.049	-0.649	19.127 (0.791)	28.986
	Residual bootstrap			19.127 (0.287)	26.577
Plog_VFD-Plog_SoFD	Fixed regressor	-0.961	0.235	43.622** (0.044)	43.253
	Residual bootstrap			43.622** (0.026)	40.22

Note: ***/**/* denotes rejection of the null at 1, 5 or 10 % significance level; the values in parentheses indicate p-value.
Source: own calculations

Table 4: SupLM test results.

Price Pairs	**$P_{log_}$CFD (P1)-$P_{log_}$NFD (P2)**		**$P_{log_}$CFD (P1)-$P_{log_}$VFD (P2)**		**$P_{log_}$VFD (P1)-$P_{log_}$SoFD (P2)**	
	Lower Regime (69.4%)	**Upper Regime (30.6%)**	**Lower Regime (28.8 %)**	**Upper Regime -71.20%**	**Lower Regime (44.8%)**	**Upper Regime (55.2%)**
Cointegrating vector, β	-1.034		-0.993		-0.961	
Threshold parameter, γ	-0.329		0.159		0.235	
ECT	-0.176***	-0.021	-0.198	-0.015	-0.21	-0.033
	-0.004	0.174	0.289	0.210*	-0.033	0.042
Constant	-0.068***	-0.012	0.041	-0.002	0.058*	0.004
	0.004	0.051	-0.035	-0.040*	0.015	-0.011
$P1_{logt-1}$	0.697***	0.391**	0.231	0.781***	0.754***	0.379***
	0.499***	0.208*	0.218	0.648***	0.692***	0.314***
$P2_{logt-1}$	0.297*	0.247	0.378*	0.002	0.414**	0.880***
	-0.165	0.457***	0.456***	0.112	0.386***	0.737***
$P1_{logt-2}$					0.218	0.04
					0.118	0.02
$P2_{logt-2}$					-0.666***	-0.631***
					-0.617***	-0.360**

Note: ***/**/* denotes rejection of the null at 1, 5 or 10 % significance level
Source: own calculations

Table 5: TVECM results.

pairs. Lag selection has been selected based on both information criterions (BIC, AIC). They provide the same results. In order to overcome some criticism on ignoring the presence of transaction costs in spatial price transmission studies, we use threshold vector error correction model. TVECM takes in account the impact of transaction costs on horizontal price transmission, without directly relying on transaction cost data. In our study TVECM shows better results for short-term relationship between Central Federal District and Volga Federal District, Southern Federal District and Volga Federal District, Southern Federal District and Volga Federal District markets compared to a linear VECM. As expected, TVECM provides a bit different results compared to the linear model. The significant difference in adjustment speeds between lower and upper regimes defends the nonlinear adjustment towards equilibrium. For the CFD-NFD price pair, in the lower regime CFD adjustment speed is rather close to that in linear VECM (-0.176 in TVECM and -0.142 in linear VECM), meanwhile, in the upper regime CFD prices move to the equilibrium at the slower speed (-0.021). TVECM estimations for the CFD and NFD market prices series defend the asymmetry in responses from the both markets. If prices are lower than the threshold, the CFD milk market adjusts by circa 18 percent and if the prices are higher than the threshold CFD milk market adjusts by approximately 2 percent. Nonlinear model suggests VFD price leadership within CFD-VFD market (statistically significant coefficient of speed adjustment is 0.21), that is in line with the fact Volga Federal district is the largest region in terms of milk production and consumption per capita. We found no short-run price adjustment to equilibrium within VFD and SoFD milk markets because adjustments to milk price changes in two regimes are statistically insignificant at the 1, 5 and 10 % levels of significance. This finding might be due to the poor transportation infrastructure and short common border between two Federal districts.

Conclusion

The paper investigates horizontal relationships between milk prices in the European part of Russia by taking into account nonlinear (threshold) effects. Price transmission was evaluated in the co-integration framework, using widely-known Johansen as well as Hansen-Seo (2002) approaches. We specify TVECM with two regimes to take into account the effects of transaction costs. Estimation results indicate that milk markets are well integrated in the long-run term. However, in the short-run some markets are only partially integrated. Based on the model estimations, we found evidence of the rather low degree of integration of milk markets with each other. The speed of adjustments in the short run is slow. Approximately 7-20 percent adjustments towards the equilibrium is observed in the linear VECM. Especially the CFD market shows the higher adjustment with another milk prices. The SoFD market is less integrated in the short-run with NFD and VFD markets. Our estimations revealed threshold effects only within three milk markets: CFD-NFD, CFD-VFD and VFD-SoFD. We found statistically insignificant price adjustments in two regimes for VFD-SoFD milk market. The Volga FD (VFD) and Southern FD (SoFD) markets appear to be isolated in the short run. This resulted from the poor transportation system and logistics infrastructure between two Federal districts (based on the Russian Government directive-2011 №1538-r about the approval of social and economic development Strategy for the Southern Federal District until 2020).

This study can be extended with including another Federal districts from Eastern part of Russia.

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References

[1] Akaike, H. (1973) "Information theory and an extension of the maximum likelihood principle", in Petrov, B. N. and Csaki, F. (eds), *Proceedings of the 2nd International Symposium on Information Theory,* Budapest: Akademiai Kiado, pp. 267-281.

[2] Andrews, D. W. K. (1993) "Tests for Parameter Instability and Structural Change with Unknown Change Point", *Econometrica*, Vol. 61, No. 4, pp. 821-856. ISSN 0012-9682. DOI 10.2307/2951764.

[3] Arnade, C., Cooke, B. and Gale, F. (2017) "Agricultural price transmission: China relationships with world commodity markets", *Journal of Commodity Markets*, Vol. 7, pp. 28-40. ISSN 2405-8513. DOI 10.1016/j.jcomm.2017.07.001.

[4] Balke, N. and Fomby, T. (1997) "Threshold Cointegration", *International Economic Review*, Vol. 38, No. 3, pp. 627-645. E-ISSN 1468-2354. DOI 10.2307/2527284.

[5] Barrett, Ch. B. (2001) "Measuring Integration and Efficiency in International Agriculture Markets", *Applied Economic Perspectives and Policy,* Vol. 23, No. 1, pp. 19-32. E-ISSN 2040-5804, ISSN 2040-5790. DOI 10.1111/1058-7195.00043.

[6] Barrett, Ch. B. and Li, J. R. (2002) "Distinguishing between equilibrium and integration in spatial price analysis", *American Journal of Agricultural Economics,* Vol. 84, No. 2, pp. 292-307. E-ISSN 1467-8276, ISSN 0002-9092. DOI 10.2139/ssrn.257342.

[7] Baulch, B. (1997) "Transfer costs, spatial arbitrage, and testing for food market integration", *American Journal of Agricultural Economics,* Vol. 79, No. 2, pp. 477-487. E-ISSN 1467-8276. ISSN 0002-9092. DOI 10.2307/1244145.

[8] Brosig, S., Glauben, T., Götz, L., Weitzel, E. and Bayaner, A. (2011) "The Turkish Wheat Market: Spatial Price Transmission and the Impact of Transaction Costs", *Agribusiness*, Vol. 27, No. 2, pp. 147-161. E-ISSN 1520-6297. DOI 10.1002/agr.20257

[9] Chen, B. and Saghaian, S. H. (2016) "Market Integration and Price Transmission in the World Rice Export Markets", *Journal of Agricultural and Resource Economics*, Vol. 41, No. 3, pp. 444-457. ISSN 1068-5502

[10] Conforti, P. (2004) "*Price Transmission in Selected Agricultural Markets*", Commodity and Trade Policy Research Working Paper, No. 7, FAO, Rome. [Online]. Available: http://www.fao.org/tempref/docrep/fao/006/ad766e/ad766e00.pdf [Accessed: 25 Nov. 2018].

[11] Dickey, D. A., Fuller, W. A. (1979) "Distribution of the estimators for autoregressive time series with a Unit Root", *Journal of the American Statistical Association*, Vol. 74, pp. 427-431. ISSN 01621459. DOI 10.1080/01621459.1979.10482531.

[12] Ganneval S. (2016) "Spatial price transmission on agricultural commodity markets under different volatility regimes", *Economic Modelling*, Vol. 52 Part A, pp. 173-185.ISSN 0264-9993. DOI 10.1016/j.econmod.2014.11.027.

[13] Granger, C. (1981) "Some Properties of Time Series Data and Their Use in Econometric Model Specification", *Journal of Econometrics*, Vol. 16, No. 1, pp. 121-130. ISSN 0304-4076. DOI 10.1016/0304-4076(81)90079-8.

[14] Engle, R. F., Granger, C. W. J. (1987) "Co-Integration and Error Correction: Representation, Estimation, and Testing", *Econometrica*, Vol. 55, No. 2, pp. 251-276. ISSN 0012-9682. DOI 10.2307/1913236.

[15] Habte, Z. (2017) "Spatial market integration and price transmission for papaya markets in Ethiopia", *Journal of Development and Agricultural Economics*, Vol. 9, No. 5, pp. 129-136. ISSN 2006-9774. DOI 10.5897/JDAE2016.0777.

[16] Hansen, B. E. and Seo, B. (2002) "Testing for Two-Regime Threshold Cointegration in Vector Error Correction Models", *Journal of Econometrics,* Vol. 110, pp. 293–318. ISSN 0304-4076. DOI 10.1016/S0304-4076(02)00097-0.

[17] Hu, Z. and Wade Brorsen, B. (2017) “Spatial Price Transmission and Efficiency in the Urea Market”, *Agribusiness,* Vol. 33, No. 1. E-ISSN 1520-6297. DOI 10.1002/agr.21475.

[18] Jena, P. K. (2016) “Commodity market integration and price transmission: Empirical evidence from India”, *Theoretical and Applied Economics*, Vol. XXIII, No. 3(608), pp. 283-306. ISSN 1844-0029.

[19] Johansen, S. (1988) “Statistical analysis of co-integration vectors”, *Journal of Economic Dynamics and Control*, Vol. 12, No. 2-3, pp. 231-254. ISSN 0165-1889. DOI 10.1016/0165-1889(88)90041-3.

[20] Johansen, S. (1991) "Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models", *Econometrica*, Vol. 59, No. 6, pp. 1551-1580. ISSN 0012-9682.

[21] Johansen, S. (1995) “*Likelihood-based Inference in Cointegrated Vector Autoregressive Models*”, Oxford University Press. ISBN-13 9780198774501. DOI 10.2307/2938278.

[22] Johansen, S. and Juselius, K. (1990) “Maximum Likelihood Estimation and Interence on Cointegration – with Applications to the Demand for Money”, *Oxford Bulletin of Economics and Statistics,* Vol. 52, No. 2, pp. 169-210. E-ISSN 1468-0084.

[23] Lütkepohl, H., Saikkonen, P. and Trenkler, C. (2001) “Maximum eigenvalue versus trace tests for the cointegrating rank of a VAR process”, *The Econometrics Journal*, Vol. 4, pp. 287-310. E-ISSN 1368-423X, ISSN 1368-4221. DOI 10.1111/1368-423X.00068.

[24] McNew, K. and Fackler, P. L. (1997) “Testing market equilibrium: Is cointegration informative?”, *Journal of Agricultural and Resource Economics*, Vol. 22, No. 2, 17, p. 191-207. ISSN 0162-1912.

[25] Minot, N. (2011) “*Transmission of World Food Price Changes to Markets in Sub-Saharan Africa*”, IFPRI Discussion Paper, No. 01059, Washington, DC. [Online]. Available: http://www.ifpri.org/publication/transmission-world-food-price-changes-markets-sub-saharan-africa [Accessed: 28 Nov. 2018].

[26] Phillips, P. C. B. and Perron, P. (1988) “Testing for a Unit Root in Time Series Regression”, *Biometrica*, Vol. 75, No. 2, pp. 335-346. E-ISSN 1464-3510, ISSN 0006-3444. DOI 10.1093/biomet/75.2.335.

[27] Savadatti P. (2018) “Spatial Market Integration of Arhar (Split) Wholesale Prices in India: Application of Vector Error Correction Model”, *Indian Journal of Marketing*, Vol. 48, No. 4, pp. 21-29. ISSN 0973-8703. DOI 10.17010/ijom/2018/v48/i4/122623.

[28] Schwarz, G. E. (1978) “Estimating the dimension of a model”, *The Annals of Statistics*, Vol. 6, No. 2, pp. 461-464. ISSN 0090-5364. DOI 10.1214/aos/1176344136.

[29] Schwert, G. W. (1989) “Tests for Unit Roots: A Monte Carlo Investigation”, *Journal of Business and Economic Statistics*, Vol. 7, pp. 147-160. ISSN 0735-0015. DOI 10.3386/t0073 .

[30] Seo, M. (2006) “Bootstrap testing for the null of no cointegration in a threshold vector error correction model”, *Journal of Econometrics*, Vol. 134, No. 1, pp. 129-150. ISSN 0304-4076. DOI 10.1016/j.jeconom.2005.06.018.

[31] Sexton, R., Kling, C. and Carman, H. (1991) “Market Integration, Efficiency of Arbitrage, and Imperfect Competition: Methodology and Application to U.S. Celery”, *American Journal of Agricultural Economics*, Vol. 7, No. 3, pp. 568-580. E-ISSN 1467-8276, ISSN 0002-9092. DOI 10.2307/1242810

[32] Stigler, M. (2013) “*Threshold cointegration: overview and implementation in R*”, R package. [Online]. Available: https://cran.r-project.org/web/packages/tsDyn/vignettes/ThCoint Overview.pdf [Accessed: 28 Nov. 2018].

[33] Wu, F. and Guan, Z. (2018) “Spatial Price Transmission in the Presence of Floor Prices”, Conference paper at the 2018 *Agricultural and Applied Economics Association Annual Meeting*, Washington, D.C., [Online]. Available: https://ageconsearch.umn.edu/record/273995 /files/Abstracts_18_05_24_10_43_35_94__128_227_173_121_0.pdf [Accessed: 20 Nov. 2018].

[34] Zakari S., Ying L. and Song B. (2014) “Market Integration and Spatial Price Transmission in Niger Grain Markets”, *African Development Review*, Vol. 26, No. 2, pp. 264-273. E-ISSN 1467-8268. DOI 10.1111/1467-8268.12080.

[35] Zhou, D. and Koemle, D. (2015) “Price transmission in hog and feed markets of China”, *Journal of Integrative Agriculture*, Vol. 14, No. 6, pp. 1122-1129. ISSN 2095-3119. DOI 10.1016/S2095-3119(14)60995-3.