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VERTICAL PRICE TRANSMISSION ANALYSIS ALONG THE CHEESE SUPPLY CHAIN

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Purpose: this paper investigates vertical price transmission along the cheese supply chain in the Russian market. *Discussion*: monthly farm-gate and retail prices in Russiacovering the period from 2003 to 2014 were used in the analysis. Prices were expressed in natural logarithms to calculate percentage change. Vertical price transmission was evaluated in the cointegration framework, using classical Engle-Granger approach. *Results*: We concluded that all price variables are integrated of the order one, I(1).Using cointegration technique, we find no empirical evidence for cointegration between farm-gate and retail prices. We show that there is unidirectional Granger causality from farm to retail prices. We built autoregressive distributed lags (ARDL) model and have estimated effects of change in farm prices on change in retail price for cheese.

Keywords: vertical price transmission, market integration, cointegration, cheese prices, Russia.

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1. Introduction

Price is the main tool by means of which different levels of the market are linked [14]. The phenomenon of price transmission attracted a plenty of scientists' attention to various commodity markets. There was a great deal of studies that applied time series econometric procedures to analyze price transmission. However, much analysis on vertical price transmission in the food markets focuses only on selected countries rather than Russia. In this context, we are motivated to study vertical price transmission along the dairy supply chain in Russia to get good insight into the price interaction at the various levels of marketing chain (farm-retail). The focus of this study is the analysis of the vertical price transmission on the cheese market in Russia. In this aspect, our purposes of analysis are:

- to carry out tests for the order of integration and co-integration of price time series in order to understand how prices move together;
- to fulfil causality test to estimate which price (farm or retail) drives another

as well as which price causes another to change;

- to estimate quantitative relationships between prices for cheese at the farm-gate and retail levels.

2. Empirical methodology

Econometric time series and multiple regression methods were adopted for price transmission analysis. The influence of farm-gate (retail) price on retail (farm-gate) price is investigated using multiple linear regressions. Initially, we consider P_{1t} to be the (natural) logarithm of retail price and P_{2t} to be the (natural) logarithm of farm-gate price.

Then we specify the model (Ansah, 2012, p.16)

$$P_{1t} = \alpha + \beta P_{2t} + \gamma G_t + \varepsilon_t, \quad (1)$$

where t – index of time, α – constant term (the log of a proportionality coefficient), β – the elasticity (magnitude) that measures the percentage change in price P_1 (retail) due to a one percentage change in price P_2 (farm-gate), G_t – government policy variable.

The estimation of price transmission magnitude (elasticity) follows the algorithm outlined in the table 1. For the pair of prices (farm-gate and retail) for whole milk, following steps will be implemented to identify the appropriate econometric model. Depending on the price series properties, various econometric models will be estimated.

Table 1

Algorithm for the vertical price transmission analysis

Step	Test	Result	Action
1	Stationarity test of time series for unit root	Stationarity	Perform test for Granger Causality and estimate vector autoregression model (VAR) with stationary data
		Non-stationarity	Move to step 2
2	Cointegration test	Exists	Estimate the Vector Error Correction model (VECM) and measure asymmetry
		No	Perform test for Granger Causality and estimate VAR model using logarithmic prices in first differences

2.1. Tests for stationarity

If there is a stationarity in the data, then equation 1 can be estimated with ordinary least squares (OLS) regression. Stationarity represents a process in which the mean and standard deviation does not change over time. But mostly price time series are non-stationary that generally leads to spurious regression. A spurious regression has significant relationship between variables but the results are in fact without any economic meaning. In the presence of non-stationary data, it is required to carry out some transformation such as differencing to make them stationary. Thus, equation 1 cannot be estimated correctly with OLS. However, pairs of non-stationary price series can have a long-term relationship between them. If a price series is differenced once (by subtracting P_{t-1} from P_t)

and the differenced series is stationary, the time series is then «integrated of order 1», denoted by I (1). Non-stationarity means presence of unit roots. A variable contains a unit root if it is non-stationary.

$$P_t = \beta P_{t-1} + \varepsilon_t . \quad (2)$$

In the equation 2 if $\beta = 1$ the model is characterised by unit root, stationarity requires that $-1 < \beta < 1$. In testing for the presence of unit roots, several methodological options are available. Widely used among them are the Augmented Dickey-Fuller (ADF) test [3] as well as the Phillips-Perron test [11].

As a standard procedure to test the non-stationarity of price series the ADF test uses following regression:

$$P_t = c + \beta t + \alpha P_{t-1} + \sum_{i=1}^{k} \psi_i \Delta P_{t-i} + \varepsilon_t , \quad (3)$$

where P_t – natural logarithm of the price, c – intercept, t – linear time trend. This regression includes k lagged first differences to account serial correlation.

Phillips-Perron test builds on ADF test. While the ADF test uses a parametric autoregression, a great advantage of PP test is that it is non-parametric, i.e. it does not require to select the level of serial correlation as in ADF. The main disadvantage of the PP test is that it works well only in large samples. And it also shares disadvantages of ADF tests: sensitivity to structural breaks, poor small sample power resulting.

The Phillips-Perron and ADF tests specify the null hypothesis that a time 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.

Elliott, Rothenberg and Stock [4] modified original version of the ADF test. The modified test, known as the ADF-GLS test, is an augmented Dickey–Fuller test, except that the time series is transformed via a generalized least squares (GLS) regression before performing the test. First, the time series is detrended by applying a GLS estimator. The ADF-GLS test is performed analogously but on GLS-detrended data. Elliott, Rothenberg, and Stock and later studies have shown that this test has significantly greater power than the previous versions of the augmented Dickey–Fuller test.

2.2. Test for co-integration

Co-integration means that prices move closely together in the long-run, while in the short-run they may drift apart. There might be a linear combination of same integrated price series that is stationary. Co-integration analysis is used to estimate long-run price relations between non-stationary and same integrated variables.

Given that some of price series will be non-stationary, we will apply conventional Granger-Engle approach to test for co-integration. Engle and Granger [5] used a technique to test for co-integration which included the static following regression estimated with OLS:

$$\tilde{P}_{1t} = \alpha + \beta \tilde{P}_{2t} + v_t \cdot \quad (4)$$

If $\tilde{P}_{1t}$ and $\tilde{P}_{2t}$ are I(1) price series, then the residuals v_t from the regression would be I(0) if they are co-integrated. So, if the residuals are I(1) we accept the null hypothesis of non-cointegration, otherwise, if the residuals are stationary, I(0), we reject the null hypothesis and accept that $\tilde{P}_{1t}$ and $\tilde{P}_{2t}$ are co-integrated.

ADF test for unit roots is applied to residuals from the co-integrating regression. First, we should test whether the price series have the same order of integration using unit root tests. If both price series have the same order of integration, we will carry out test for co-integration between the prices.

2.3. The Granger causality analysis

After testing for co-integration we will apply the Granger Causality test [7] to evaluate the possible direction of the price transmission. The basic principle of Granger causality is that two variables P_{1t} and P_{2t} can have influence on one another.

$$P_{2t} = \sum_{i=1}^{n} \alpha_i P_{2t-i} + \sum_{j=1}^{q} \beta_j P_{1t-j} + \upsilon_t, \tag{5}$$

where υ_t – the white noise, n, q – the lag order of P_2 and P_1 variables respectively.

In our study, P_2 and P_1 is the retail and farm-gate prices, the α's and β's are parameters. We test for the significance of the β's and if they are jointly significant, then we conclude that P_1 Granger causes P_2. We assume that there is a linear relationship between the farm-gate and retail prices. The Granger causality test needs that the variables should be stationary. In order to determine the optimum lags in the models, the Akaike [1] information criterion (AIC) and the Schwarz-Bayesian [12] information criterion (BIC) are used. Serena and Perron [14] proposed the modified versions of AIC (mAIC) and BIC (mBIC) as a model selection criterion which are based on quasi-likelihood function.

2.4. VECM/VAR Models

If the price series are co-integrated we estimate a Vector Error Correction model (VECM), otherwise, we build Vector Autoregression model (VAR) for farm-gate and retail prices in order to investigate price dynamic relationships.

The VECM is a special case of VAR models that takes into account co-integration relationships between price series. The general equation of the VECM model is following:

$$\Delta P_{2t} = \alpha + \rho\left(\Delta P_{2t-1} - \beta \Delta P_{1t-1}\right) + \delta \Delta P_{1t-1} + \theta \Delta P_{2t-1} + \varepsilon_t, \tag{6}$$

where ΔP_{2t} and ΔP_{1t} – change in retail and farm-gate prices respectively; ΔP_{2t-1} and ΔP_{1t-1} – lagged change in retail and farm-gate prices respectively; ρ – error correction term (speed of adjustment to long-run equilibrium); β – long-run elasticity of price transmission; δ – short-run elasticity of price transmission between two prices, ε_t – residual (white noise).

If our tests reveal non-cointegration, we can specify and estimate VAR model. The VAR model includes two equations and can be written as equations 7, 8:

$$P_{1t} = \alpha_0 + \alpha_1 P_{1t-1} + ... + \alpha_k P_{1t-k} + \gamma_1 P_{2t-1} + ... + \gamma_k P_{2t-k} + \varepsilon_t , \quad (7)$$

$$P_{2t} = \beta_0 + \beta_1 P_{2t-1} + ... + \beta_k P_{2t-k} + c_1 P_{1t-1} + ... + c_k P_{1t-k} + \varepsilon_t t , \quad (8)$$

where P_{1t} and P_{2t} – farm-gate and retail prices, P_{1t-k} and P_{2t-k} – lagged farm-gate and retail prices.

The model includes the causality results. As a drawback, individual coefficients in the estimated VAR models are often difficult to interpret, users of this technique often estimate the impulse response function. The VAR model generates the impulse response function that indicates us about how fast a price shock at one price transmits towards another price. It describes the response of one variable to an impulse of another variable.

If test reveals unidirectional Granger causality running from the farm-gate (retail) to the retail (farm-gate) price then we can specify Autoregressive Distributed-Lags model (ARDL) and estimate immediate and dynamic effects (magnitude of price transmission) of one price on another. The ARDL model can be written as equation 9:

$$P_{2t} = \beta_0 + \beta_1 P_{2t-1} + ... + \beta_k P_{2t-k} + \delta_0 P_{1t} + \delta_1 P_{1t-1} ... + \delta_k P_{1t-k} + \varepsilon_t , \quad (9)$$

where P_{1t} and P_{2t} – farm-gate and retail prices, P_{1t-k} and P_{2t-k} – lagged farm-gate and retail prices, δ_0 – immediate effect of change in farm-gate price on retail price (elasticity).

3. Data and empirical results

The price transmission analysis has been carried out using 142 monthly observations from January, 2003 to October, 2014 at the farm-gate and retail levels in Russian Federation. Observations relate to nominal prices for cheese per kilogram. The source of the data is the Federal State Statistics Service of Russian Federation.

In order to measure the farm-gate value of cheese, we use farm-gate prices for milk and Van Slyke formula (10) for cheese yield [17]. This formula estimates the amount of cheese that can be produced from milk given the composition of the milk, the recovery of milk fat in the cheese, and the moisture content of the cheese.

$$CheeseYield, kg = \frac{(0{,}93F + C - 0{,}10) \times 109}{100 - M} , \quad (10)$$

where F – milk fat, C – milk casein, M – moisture content of cheese

For instance, production of one kilogram of cheese requires approximately 10 kilograms of milk. Besides, cheese producers also sell dry whey to cover costs for the milk. We adjusted the farm value of the cheese with the value of any dry whey that can be produced as a coproduct and sold.

We use the logarithmic transformation of monthly prices measured in Russian rubles. From an economic point of view, this transformation allows us to interpret results in percentage change terms. Chain from farmers to retailers in Russia is investigated (see figure).

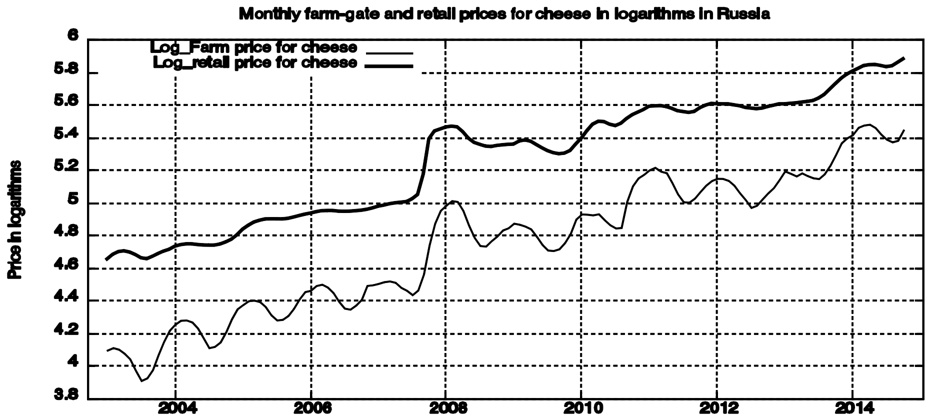

Fig. Price series in logarithms along the supply chain for cheese in Russia

Using the methodology described above, we started analysing of price series with the tests of stationarity. Stationarity of the price series was checked with the conventional ADF test, ADF-GLS test and Phillips-Perron test. In order to select the highest number of lags for our tests we applied the common rule for determining Pmax, suggested be Schwert [13]:

$$P_{\max} = 12 \times \sqrt[4]{\frac{T}{100}}, \quad (11)$$

where T – sample size.

The number of optimal lags was determined using modified Schwarz-Bayesian information criterion (mBIC). Our preliminary visual examination of price series graphs gives us the insight that model for unit-root test should contain constant and a time trend. The null hypothesis H0 is rejected if the critical value is greater than test statistic (p-value is less than level of significance). The results are summarized in table 2.

Table 2

Unit root test results in levels and first differences

Price variable (log price)	Model	ADF test				ADF-GLS test				Phillips-Perron test			
		Lag	Levels	Lag	First difference	Lag	Levels	Lag	First difference	Lag	Levels	Lag	First difference
Farm price (cheese)	Trend & intercept	8	-2,1 (0,546)	1	-6,345***	8	-2,156	1	-6,352***	8	-2,972	1	-5,015***
	Intercept only	8	-0,423 (0,903)	1	-6,369***	2	0,467 (0,816)	1	-6,349***	8	-0,669	1	-5,018***
Retail price (cheese)	Trend & intercept	2	-2,966 (0,142)	2	-5,101***	2	-2,982**	2	-4,747***	7	-2,619	2	-5,562***
	Intercept only	7	-0,635 (0,861)	2	-5,12***	1	0,766 (0,879)	10	-1,972**	7	-0,617	2	-5,562***

Notes: 1) ** – null hypothesis of non-stationarity rejected at 5% of significance; *** – null hypothesis of non-stationarity rejected at 1 % of significance; 2) the value in parentheses indicates p-value.

The output presented in table 2 shows that null hypothesis of stationary price series was rejected for all variables except for retail price for cheese. The lag length selected by mBIC was 2. However, at higher lag length the null hypothesis of stationarity for retail price series for cheese was rejected as well. Tests based on first differences show that all the test statistics are significant at 1% critical level. Hence, we can conclude that all price variables are integrated of the order one, I (1). Our findings allow us to assume that there is co-integration between farm and retail prices for cheese which is required to be investigated.

We run the conventional test of Engle and Granger. Within this test for co-integration the static equation (4) is first estimated with OLS and then the stationarity of the residuals of the relationship between farm and retail prices is tested with the ADF test using the critical values proposed by MacKinnon [10]. If the residuals are revealed to be stationary, the price pair is identified to be cointegrated. We set the maximum lag in accordance with equation 11 and used the information criterion to select appropriate lag lengths. ADF test statistics for Engle-Granger test are shown in table 3.

Table 3

Cointegration test (Engle-Granger test)

Price pair (in logarithms)	Test value	
	Intercept only	Trend & intercept
Cheese (farm-retail)	-2,234 (0,406)	-2,333 (0,611)

Notes: the value in parentheses indicates p-value (level of significance)

As we can see from the table 3, we cannot reject the null hypothesis of non-cointegration in cheese farm-retail chain. Hence, we found that price pair is not co-integrated and we will specify and estimate VAR model in first differences. However, firstly, we should implement Granger causality F-tests of zero restrictions within the framework of VAR.

In order to estimate the possible direction of price transmission, we carried out causality test (see table 4). The appropriate lag length was selected in accordance with BIC (Schwarz-Bayesian information criterion) and HQC (Hannan-Quinn criterion). In order to avoid autocorrelation problem we computed HAC (heteroskedasticity and autocorrelation-consistent) standard errors within the model.

Table 4

Granger causality F-test

Null Hypothesis	F-statistics, (p-value)	Conclusion
ΔlnFarm does not cause ΔlnRetail (lag 2)	2,951* (0,056)	Reject
ΔlnRetail does not cause ΔlnFarm (lag 2)	1,636 (0,199)	Accept

Notes: 1) ΔlnFarm – farm log-price for cheese (in first difference); ΔlnRetail – retail log-price for cheese (in first difference); 2) *** – 1 % significance level; ** – 5% significance level; * – 10 % significance level

As shown in table 4, the direction of price transmission goes from farmers to retailers but not vice versa. According to our findings, we can specify ARDL model and estimate immediate and dynamic effects of farm price on retail price for cheese (table 5).

Table 5

Estimation results (model specification) for cheese farm-retail chain, dependent variable Δln_RetailPricet

Variables	Coefficient	Std.error	t-statistic	Significance (p-value)
Intercept	0,00336**	0,00141	2,3923	0,0181
Δln_RetailPricet-1	0,59865***	0,21602	2,7711	0,0064
Δln_RetailPricet-2	-0,23509**	0,09972	-2,3572	0,0198
Δln_FarmPricet	0,21622**	0,08955	2,4151	0,0171
R^2	0,59760	-	-	-
Adjusted R^2	0,58866	-	-	-
F-statistic	23,86005	-	-	1,88e-12

Notes: Since following variables: Δln_RetailPricet-3…Δln_RetailPricet-k, Δln_FarmPricet-1…Δln_FarmPricet-k are statistically insignificant and also have not significant effect on the whole regression model, these variables were eliminated from the model.

Hence, according to the calculated price transmission elasticity, there is evidence that 1% increase in farm price for cheese results in 0,22 % increase in retail price.

4. Conclusions

In this study we have investigated relationship between the farm-gate and retail prices for cheese in Russia. Monthly farm-gate and retail prices over period January 2003 through October 2014 were used in the analysis. Prices were expressed in natural logarithms to calculate percentage change. The data is integrated of order one.

Vertical price transmission was evaluated in the cointegration framework, using classical Engle-Granger approach. The results have shown that a long-run cointegration relationship does not exist between farm and retail prices, that is, they do not move together. We have found evidence that change in one price has a significant effect on another one, that is, Granger test established unidirectional causality from farm to retail prices and not vice versa. Further research on the topic would be extension of our study, having included wholesale stage in the analysis to better understand price links along the dairy supply chain. Further research is also needed to investigate price transmission with including wholesale level in the analysis as well as using a wider range of advanced unit root and cointegration tests under structural breaks.

References

1. Akaike H. Information theory and an extension of the maximum likelihood principle. *Second International Symposium on Information Theory*, AkademiaiKiado, Budapest, 1973, pp. 267-281.

2. Ansah I.G.K. *Analyzing the relationship*

between world market prices and local prices of food in African markets: the case of wheat in Ethiopia. MSc Thesis, Wageningen University and Research Center, Wageningen, 2012.

3. Dickey D.A., Fuller W.A. Distribution of the estimators for autoregressive time series with a Unit Root. *Journal of the American Statistical Association*, 1979, no. 74, pp. 427-431

4. Elliott G., Rothenberg T.J., Stock J.H. Efficient Tests for an Autoregressive Unit Root. *Econometrica*, 1996, vol. 64, no. 4, pp. 813-836. doi:10.2307/2171846

5. Engle R.F., Granger C.W.J. Co-Integration and Error Correction: Representation, Estimation, and Testing. *Econometrica*, 1987, vol. 55, no. 2, pp. 251-276.

6. Granger C.W.J. Investigating Causal Relations by Econometric Models and Cross-spectral Methods. *Econometrica*, 1969, vol. 37, no. 3, pp. 424-438. doi:10.2307/1912791

7. Granger C.W.J. Testing for causality: A personal viewpoint. *Journal of Economic Dynamics and Control*, 1980, no. 2, pp. 329-352. doi:10.1016/0165-1889(80)90069-X

8. Granger C.W.J., Lee T.H. Investigation of production, sales and inventory relationships using multicointegration and non-symmetric error correction models. *Journal of Applied Econometrics*, 1989, no. 4, pp. 145-159. doi: 10.1002/jae.3950040508

9. Hamilton J.D. *Time series analysis*. Princeton University Press, Princeton, NJ, 1994.

10. MacKinnon J. Critical Values for Cointegration Tests. In Engle R., Granger C. *Long-Run Economic Relationships*. Oxford University Press, Oxford, 1991.

11. Phillips P.C.B., Perron P. Testing for a Unit Root in Time Series Regression. *Biometrica*, 1988, vol. 75, no. 2, pp. 335-346. doi:10.1093/biomet/75.2.335

12. Schwarz G. Estimating the dimension of a model. *The Annals of Statistics*, 1978, no. 6, pp. 461-464. doi:10.1214/aos/1176344136

13. Schwert G.W. Tests for Unit Roots: A Monte Carlo Investigation. *Journal of Business and Economic Statistics*, 1989, vol. 7, no. 2, pp. 147-160. doi:10.2307/1391432

14. Serra T., Goodwin B. Price transmission and asymmetric adjustment in the Spanish dairy sector. *Paper presented at the Annual Meeting of the American Agricultural Economics Association*, Long Beach, CA, July 28-31, 2002.

15. Serena Ng, Perron, P. Lag Length Selection and the Construction of Unit Root Tests with Good Size and Power. *Econometrica*, 2001, vol. 69, no. 6, pp. 1519-1554.

16. Sims C. Macroeconomics and Reality. *Econometrica*, 1980, vol. 48, no. 1, pp. 1-48. doi: 10.2307/1912017

17. Stewart H., Blayney D. Retail dairy prices fluctuate with the farm value of milk. *Agricultural and Resource Economics Review,* 2011, vol. 40, no. 1, pp. 201-217.

АНАЛИЗ ВЕРТИКАЛЬНОЙ ТРАНСМИССИИ ЦЕН НА РЫНКЕ СЫРА

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Цель: анализ ценовой трансмиссии на российском рынке сыра. *Обсуждение*: для анализа используются временные ряды месячных цен сыров в России за период с 2003 по 2014 год. Исследование ценовой трансмиссии осуществляется посредством тестирования временных рядов на стационарность, коинтеграцию, причинно-следственную связь. *Результаты*: в ходе анализа выявлено, что ценовые ряды являются интегрированными первого порядка, однако между ними нет коинтеграции. Причинно-следственная связь по Грэнджеру существует в направлении от цен «фермера» к розничным. Посредством построения модели авторегрессии и распределенных лагов был оценен эффект влияния изменения фермерских цен на изменение розничных. В частности, при изменении фермерских цен сыров на 1 %, розничная цена меняется на 0,22 % в краткосрочном периоде.

Ключевые слова: вертикальная трансмиссия цен, рыночная интеграция, коинтеграция, цены сыров, Россия.

Список источников

1. Akaike H. Information theory and an extension of the maximum likelihood principle // *Second International Symposium on Information Theory,* AkademiaiKiado, Budapest, 1973, pp. 267-281.

2. Ansah I.G.K. *Analyzing the relationship between world market prices and local prices of food in African markets: the case of wheat in Ethiopia*. MSc Thesis, Wageningen University and Research Center, Wageningen, 2012.

3. Dickey D.A., Fuller W.A. Distribution of the estimators for autoregressive time series with a Unit Root // *Journal of the American Statistical Association*, 1979, no. 74, pp. 427-431

4. Elliott G., Rothenberg T.J., Stock J.H. Efficient Tests for an Autoregressive Unit Root // *Econometrica*, 1996, vol. 64, no. 4, pp. 813-836. doi:10.2307/2171846

5. Engle R.F., Granger C.W.J. Co-Integration and Error Correction: Representation, Estimation, and Testing // *Econometrica*, 1987, vol. 55, no. 2, pp. 251-276.

6. Granger C.W.J. Investigating Causal Relations by Econometric Models and Cross-spectral Methods // *Econometrica*, 1969, vol. 37, no. 3, pp. 424-438. doi:10.2307/1912791

7. Granger C.W.J. Testing for causality: A personal viewpoint // *Journal of Economic Dynamics and Control*, 1980, no. 2, pp. 329-352. doi:10.1016/0165-1889(80)90069-X

8. Granger C.W.J., Lee T.H. Investigation of production, sales and inventory relationships using multicointegration and non-symmetric error correction models // *Journal of Applied Econometrics*, 1989, no. 4, pp. 145-159. doi: 10.1002/jae.3950040508

9. Hamilton J.D. *Time series analysis.* Princeton University Press, Princeton, NJ, 1994.

10. MacKinnon J. Critical Values for Cointegration Tests. In Engle R., Granger C. *Long-Run Economic Relationships*. Oxford University Press, Oxford, 1991.

11. Phillips P.C.B., Perron P. Testing for a Unit Root in Time Series Regression // *Biometrica*, 1988, vol. 75, no. 2, pp. 335-346. doi:10.1093/biomet/75.2.335

12. Schwarz G. Estimating the dimension of a model // *The Annals of Statistics*, 1978, no. 6, pp. 461-464. doi:10.1214/aos/1176344136

13. Schwert G.W. Tests for Unit Roots: A Monte Carlo Investigation // *Journal of Business and Economic Statistics*, 1989, vol. 7, no. 2, pp. 147-160. doi:10.2307/1391432

14. Serra T., Goodwin B. Price transmission and asymmetric adjustment in the Spanish dairy sector. *Paper presented at the Annual Meeting of the American Agricultural Economics Association*, Long Beach, CA, July 28-31, 2002.

15. Serena Ng, Perron, P. Lag Length Selection and the Construction of Unit Root Tests with Good Size and Power // *Econometrica*, 2001, vol. 69, no. 6, pp. 1519-1554.

16. Sims C. Macroeconomics and Reality // *Econometrica*, 1980, vol. 48, no. 1, pp. 1-48. doi: 10.2307/1912017

17. Stewart H., Blayney D. Retail dairy prices fluctuate with the farm value of milk // *Agricultural and Resource Economics Review*, 2011, vol. 40, no. 1, pp. 201-217.