Asymmetry in Price Transmission: Evidence from the Wheat-Flour Supply Chain in Russia

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Abstract

Price volatility has serious implications for economic welfare of various agents in the grain supply chain. The paper examines asymmetric price transmission along the wheat producer-processor supply chain in Russia using log-transformed monthly prices during the period of 2000-2019. Having specified linear asymmetric vector error correction model, we exposed the long-term cumulative asymmetry in price transmission, however, the hypothesis of short-term symmetry presence failed to reject. The analysis revealed dominant position for wheat producers and wholesalers over the wheat processors. Imperfect competition and their resulting market power, as well as the existence of a huge number of illegal processors are the main causes for asymmetric price transmission on the Russian wheat market.

Keywords

Price transmission, asymmetry, grain market, Russia, food.

Introduction

The grain market is the largest agricultural market in Russia. Grain is one of the key products for both food industry and livestock companies.

Russian grain production exceeds domestic consumption and thereby orients on export. Over the past five years the volume of grain production has shown steady positive growth dynamics mainly due to the existence of favorable weather conditions for the main grain crop - wheat. More than third of grain produce is exported, although, increasing the grain export potential is limited by the insufficient level of logistics infrastructure development. Exporters purchase as well as change in the exchange Russian ruble rate effect significantly on the grain pricing in Russia.

In the contrast, Russian flour production has been declining for several years on end. Since 2013, the production volume has not exceeded 10 million tons. Moreover, since 2015 production has been steadily reducing to 9.4 million tons in 2018. Export possibility can really be a good support for the industry. However, Russian flour export does not match the competitors in price. Russia's share in the world flour trade does not exceed 2 %, that is less than the share of Turkey, Kazakhstan, Argentina and Ukraine put apart. In order to compete efficiently on the world flour market government support measures are required. Flour producers have the perception that there is price disparity and the price changes are not efficiently transmitted through farmer-processor supply chain.

Prices play an important role in a market economy. Price volatility has serious implications for economic welfare of various agents in the food supply chain, and therefore, it is worth studying vertical price transmission to provide recommendations for policymakers. The presence of asymmetric price transmission (APT) tends to be characteristic of market imperfection resulting from a various reasons. The examination of APT can provide information indirectly about the income distribution amongst the different levels of a vertical supply chain which is of high importance in the area of welfare analyses (Szőke et al., 2019). Price transmission analysis in the aspect of asymmetries presence is a key determinant of food security, especially in emerging markets such as Russian.

There exists a large literature on price transmission in agro-food sectors. Most of the literature

on price transmission in the cereals markets relies on multiple regressions of lagged price differences as well as linear or non-linear modeling to identify asymmetric price relationships.

Brümmer et al. (2009) used a Markov-switching vector error-correction model (MSVECM) to model multiple regime shifts in the relationship between wheat and wheat flour prices in Ukraine. The analysis revealed four regimes whose timing coincides with political and economic events in Ukraine. Although causality ran both ways, this suggested that much policy intervention in response to shocks to Ukraine's wheat and flour markets might have increased rather than reduced instability. Cinar (2018) examined the price volatilities in Turkish cereal markets by means of the Baba-Engle-Kraft-Kroner (BEKK) version of the multivariate Generalized Autoregressive Heteroskedastic (MGARCH) method. His findings of the BEKK MGARCH model provided evidence that there was a one-way, strong and permanent volatility spillover from the corn and barley market to the wheat market. Hassouneh et al. (2017) studied producer and consumer wheat prices in Slovenia having applied a threshold vector error correction and multivariate generalized autoregressive conditional heteroscedasticity model with exogenous variables. Results indicated that price-level adjustments mainly favour retailers by increasing their marketing margins.

Wu et al. (2019) tested the asymmetry of vertical price transmission in two Nigerian cowpea markets with using the autoregressive distributed lag model and asymmetric error correction model. Results suggested that price transmission in one market is symmetric, but it is asymmetric in another. Ricci et al. (2019) analyzed vertical price transmission in two typical Italian wheat chains, the pasta and bread chains. The authors detected the evidence of asymmetric price transmission having applied a co-integration methodology. Haile et al. (2017) assessed the degree of vertical price transmission along the wheat-bread value chain in Ethiopia by applying a vector error correction model and an impulse response analysis on the base of monthly price data. The empirical findings indicated that price changes were not transmitted efficiently as well as significant co-integration and causal relationships existed between prices at the different market stages. Rumankova (2014) used vector error correction model and impulse-response analysis to defend a(symmetrical) nature of price transmission along the Czech wheat agro-food chain. Usman and Haile (2017) investigated producer-retailer price transmission on the two

Ethiopian major cereal markets with using specific asymmetric error correction models. They gave evidence of asymmetric price transmission for the wheat market in one of the regions, unlike the wheat market in another one, indicating some differential in the quality of infrastructure and the length and complexity of wheat value chains between two markets. Louw et al. (2017) used time series econometric techniques to study vertical price transmission across two value chains in South Africa. Their results indicated full price transmission in the wheat-to-bread chain but incomplete price transmission in the maize-to-maize meal chain. Symmetry in price adjustment was not rejected in both chains. Liu et al. (2012) estimated the elasticity of farm-gate prices to retail ones for twelve major products (incl. wheat), having specified linear regression models with two proxies (infrastructure level and population density in Chinese provinces). The authors found strong linkages between retail and farm-gate prices that have continually been intensifying since the policy retrenchment period in 1995.

Taking into account the significant changes of the food sector in emerging markets, the need to get insight into magnitude, speed, asymmetry of price transmission as well as factors behind price transmission, is as reasonable as ever. There exists certain gap in the research literature on vertical price transmission, as well (a)symmetries presence in the Russian grain supply chain, that this paper seeks to feel. The purpose of the paper is to expose price transmission features and evaluate the asymmetric price transmission in the Russian wheat market (i.e., from farm-gate to the wholesale market) by means of the most popular econometric models and reveal the causes of asymmetries.

Materials and methods

Our price transmission study has been carried out using monthly observations related to average nominal prices for wheat, wheat flour at the farmer and processor levels from January 2000 to December 2019 in Russian Federation. The number of observations is sufficient, that is desirable since the larger sample, the more robust our results are. The source of the data is the Federal State Statistics Service of Russia (available online at **http://www.gks.ru**). We use the logarithmic transformation of monthly prices measured in Russian rubles per ton in order to compute price elasticities and mitigate price series fluctuations. Transformation allows the results to be interpreted in percentage change terms.

Firstly, we run preliminary tests to identify price series features and then the empirical model will be specified and estimated. Wheat and flour price relationships are investigated by means of multiple linear regression analysis.

Regressing non-stationary time series can lead to spurious regression thereby having resulted in model misspecification. In order to identify the unit root presence, we ran Augmented Dickey-Fuller (ADF) (Dickey and Fuller, 1979) and KPSS tests (Kwiatkowski et al., 1992). ADF test specifies the null hypothesis that the price series is non-stationary, i.e. unit root is present.

To test the non-stationarity of price series the ADF test uses following regression:

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

where P_t – log-transformed price, c – intercept, t-linear time trend. This regression includes k lagged first differences to account serial correlation.

KPSS test assumes the null hypothesis (H0): stationary time series versus alternative (Ha): non-stationarity in time series. The KPSS test offers a complement to the ADF test to intensify econometric inference.

The number of the optimum lags was chosen based on the Akaike (1973) information criterion (AIC).

As a next step, we should test our time series for cointegration. Often time series behave similarly over time and have same stochastic trend. Such time series are considered co-integrated. In that case we obtain super-consistent OLS-estimates for the model parameters. Granger (1981) introduced the cointegration technique. Then the cointegration concept was followed up by Engle and Granger (1987), Johansen (1988), Johansen (1991), Johansen (1995), Phillips and Ouliaris (1990), Gregory and Hansen (1996) and Hatemi (2008).

In order to check the price series and determine the cointegrating rank we applied the Johansen methodology (Johansen, 1991; Johansen, 1992) based on maximum likelihood estimation. Unlike some of the tests, it avoids the issue of choosing a dependent variable. In order to determine the number of cointegrating vectors, Johansen has proposed two different likelihood ratio tests: the trace test and the maximum eigenvalue test shown below in the equations 2, 3 respectively. The tests also generate maximum likelihood estimates of the parameters in a vector error-correction (VEC) model of the cointegrated time series.

$$LR_{(r,n)} = -T \sum_{i=r+1}^{n} \ln(1 - \check{\lambda}_i) \quad (2)$$

$$LR_{(r,r+1)} = -T\ln(1 - \check{\lambda}_{r+1}) \quad (3)$$

where $LR_{(r,n)}$ is the likelihood ratio statistic for testing whether rank $(\Pi) = r$ versus the alternative hypothesis that rank $(\Pi) \leq n$; $LR_{(r,r+1)}$ is the likelihood ratio test statistic for testing whether rank $(\Pi) = r$ versus the alternative hypothesis that rank $(\Pi) = r + 1$; n is the number of variables; r is the number of cointegrating relationships; T is the sample size; $\check{\lambda}$ is the i-th largest canonical correlation; Π is the coefficient matrix obtained from the VAR model, where $\Pi = \alpha\beta'$, α are known as the error correction terms in the vector error correction model (VECM) and each column of β is a cointegrating vector in the long run.

The likelihood ratio statistics do not have the conventional χ^2 distribution. Asymptotic critical values are given by Johansen and Juselius (1990). If two tests provide contradictory results, we are going to rely on trace statistic since it tends to have superior power in empirical studies (Lutkepohl et al., 2001).

Our dataset is based on monthly observations, a seasonal component is reasonable to be taken into consideration as well. The approach that helps to reveal seasonal unit roots was developed by Hylleberg et al. (1990). However, in order to produce robust and better results HEGY test needs a rather long time series (30-60 years), otherwise, that would bias estimation results since "asymptotics" works, taken into account number of years, not the number of observations. More observations would also make it possible to explore seasonality in seasonal VECM parameters. Unfortunately, we have less than 20-years price series. There are some problems with seasonal cointegration interpretation, especially for assymetric price transmission analysis. We use piecewise linear cointegration methods (AVECM), which are based on the assumption that at any given time price transmission follows one of two linear error correction regimes. In the Assymetric VECM, for example, prices follow one of two linear error correction processes depending on whether positive or negative deviations from the long-run equilibrium relationship are being corrected (wheat price decreased in the summer-autumn, and opposite in the winter-spring).

The cointegrating price series have error correction

model representation as a special case of Vector Autoregression (VAR) models. The modeling of asymmetric price transmission can be classified into precointegration and cointegration techniques (Meyer and von Cramon-Taubadel, 2004; Frey and Manera, 2007). VECM has become the 'workhorse' model in analyzing asymmetric price transmission, and which adequately represents time series behavior in the presence of non-stationarity and cointegration (Hassouneh et al., 2012). In order to take into account asymmetric adjustments, assymetric VECM (AVECM) alternative have been proposed by decomposing variable first differences and error correction terms into positive and negative components (Granger and Lee, 1989; von Cramon-Taubadel, 1998).

In our study we specify linear AVECM which can be defined as follows:

$$\Delta P_t^{out} = c + \sum_{i=1}^{k} a_i^+ D_{t-i}^+ \Delta P_{t-i}^{out} + \sum_{i=1}^{l} a_i^- D_{t-i}^- \Delta P_{t-i}^{out}$$
$$+ \sum_{j=1}^{m} \beta_j^+ D_{t-j}^+ \Delta P_{t-j+1}^{in} + \sum_{j=1}^{n} \beta_j^- D_{t-j}^- \Delta P_{t-j+1}^{in}$$
$$+ \varphi^+ ECT_{t-1}^+ + \varphi^- ECT_{t-1}^- + \varepsilon_t \qquad (4)$$

where, Δ is the difference operator; P_t^{out} and P_t^{in} are the logarithms of the output (wheat or flour prices) and input (wheat or flour) prices respectively; c is the constant; D_t^+ and D_t^- are the dummy variables indicating the sign of the lagged price variables P_t^{out} and ΔP_t^{in} (to capture asymmetry, the dummies are used when wheat (flour) prices increase or fall respectively); $ECT_{(t-1)}^+$ and $ECT_{(t-1)}^-$ are positive and negative error correction terms obtained as the residuals from the long-run relationship between price variables, equal to $ECT_{t-1} = P_{t-1}^{out} - \widetilde{\alpha_0} - \widetilde{\alpha_1} P_{t-1}^{in}$; ε_t is a vector of i.i.d random errors.

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. To detect the presence asymmetric price transmission, we apply F-tests for linear restrictions via the following null hypotheses:

H$_0$: $\varphi^+ = \varphi^-$, the speed of adjustment to the long-run equilibrium is symmetric;

H$_0$: $\beta_j^+ = \beta_j^-$, distributed lag effect symmetry in price transmission magnitude at each lag;

H$_0$: $\sum_{j=1}^{m} \beta_j^+ = \sum_{j=1}^{n} \beta_j^-$, cumulative symmetry of all lags.

Asymmetric price transmission between our two time series is evaluated using open-source package "apt" in the econometric software "R" developed by Dr. Changyou Sun (2016).

Results and discussion

The price development at two levels over the period of 2000-2019 can be observed in Figure 1. Visual plot examination gives the insight about probable price series non-stationarity. As seen from the Figure 1, prices appear to move synchronously with the common upward trend during the period. Therefore, some kind of price transmission with possible long-run relationship might be present.

Taking the econometric techniques described above into account, we get started our analysis with checking the transformed price series in natural logarithms for stationarity. Price series have a changing mean, therefore constant worth being included in the models for unit root tests. (Non) stationarity of the price series has been identified with the ADF and KPSS tests. The highest lag is based on Schwert rule (Schwert, 1989). We defined it as follows:

$$P_{max} = 12 \times \sqrt[4]{\frac{N}{100}} \qquad (5)$$

where N is sample size.

To choose the optimal lag order we oriented on the information criterion. Our findings are shown in the table 1. According to the ADF test, the null of stationary log-transformed time series in levels has been rejected for two variables. Testing based on first differences revealed significant test statistics at 1 per cent. KPSS test can be used interchangeably with the ADF test. A key difference from ADF test is the null hypothesis of the KPSS test is that the series is stationary. So practically, the interpretation of p-value is just the opposite to each other. That is, if p-value is < significance level, then the series is non-stationary. Whereas in ADF test, it would mean the tested series is stationary. Therefore, the unit root tests in the table below show that both log-transformed price variables are the same integrated, i.e. I (1).

Therefore, as a next step we can perform cointegration test between price pair. Cointegration 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.
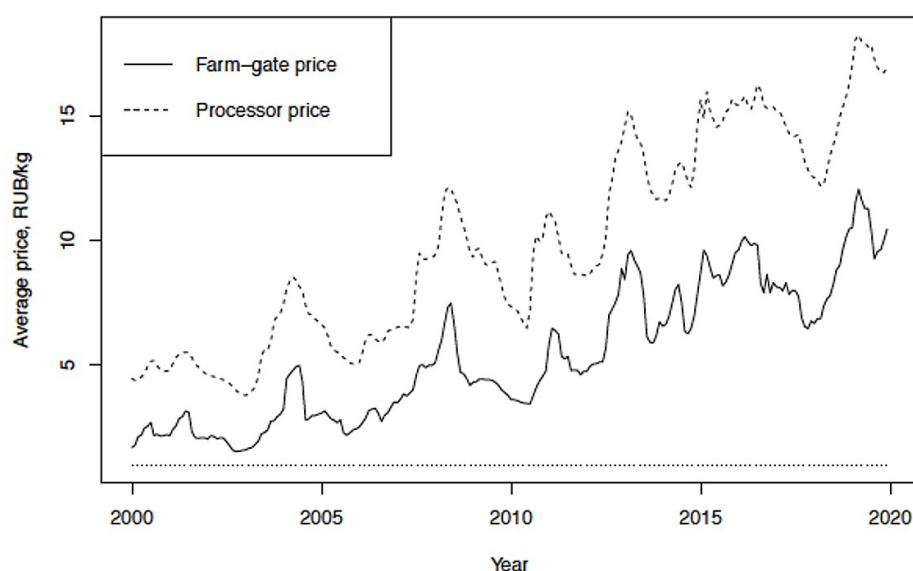
Co-integration analysis is used to estimate long-run price relations between non-stationary and same integrated variables.

Given that our price series are I (1), we have run Johansen test to reveal if the non-stationary series are co-integrated. The optimal lag for testing has been selected in accordance with the Akaike information criterion as a result of VAR modeling. As shown in Table 2, we identified one co-integrating equation for farm-processor supply chain.

According to the Johansen test based on the trace and maximum eigenvalue statistics, we can reject the null hypothesis of $r = 0$ and fail to reject the null of $r \leq 1$ at the 1, 5, 10 % significance levels.

Therefore, the log-transformed price series are co-integrated and demonstrate long-term relationships with common stochastic trend.

As a result of co-integration between the time series, we are able to specify an asymmetric VECM for the price pair. To avoid autocorrelation problem, heteroskedasticity and autocorrelation-consistent White standard errors have been computed (White, 1980). As seen from the Table 3, statistical model diagnostic revealed that AVECM is well specified since the residuals are normally distributed as well as do not suffer from serial autocorrelation and heteroskedasticity, that is preferable. The ECT coefficients are statistically significant and carry

Source: Federal State Statistics Service of Russia

Figure 1: Current producer prices for wheat and flour in the Russian Federation, January 2000 - December 2019.

Price variable in logarithms	ADF test				KPSS test			
	Lag	Levels	Lag	1st difference	Lag	Levels	Lag	1st difference
FP	7	-1.398	6	-6.122***	14	1.562***	14	0.030
PP	3	-1.494	2	-6.433***	14	1.566***	14	0.025

Note: */**/*** null hypothesis of non-stationarity rejected at 10%, 5% and 1% of significance; FP – farm-gate wheat price, PP – Processor price for flour
Source: own calculations

Table 1: Unit root test results.

Log-transformed price series	Hypothesized number of co-integrating equation	Trace statistics	Max-Eigen values
FP-PP	None (r=0)	42.28***	39.05***
	At most 1 (r≤1)	2.43	3.24

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

Table 2: Johansen co-integration test for log-transformed price series.

the negative sign, that implies model stability, the convergence to equilibrium and long-term causality from the processor prices to farm-gate ones.

The results from the Table 3 imply that short-run symmetry exists at a given moment in time since the null hypothesis (H_0: $\beta_j^+ = \beta_j^-$) fails to reject at a 5 % significance level. One should pay attention to the sample size choosing a significance level. If the sample size is small (less than 100 observations), it is possible to reject the null hypothesis at a significance level of even 10 %. Our price series are more than 200 observations, hence, we can use 1 % and 5 % significance level. 5 % of significance is a feasible level at which to do empirical research.

However, long-term asymmetry in magnitude changes is available. The null of cumulated symmetry ($\sum_{j=1}^{m} \beta_j^+ = \sum_{j=1}^{n} \beta_j^-$) is rejected at a 5 % of significance. The cumulative positive changes in processor prices are transmitted differently to the changes in farm-gate wheat price in comparison with negative changes in processor price.

The estimation results on the long-term relation between log-transformed FP and PP show that a 1 % change in processor prices leads to 1.21 % change in farm-gate wheat prices. Therefore, we can observe an imperfect market structure. The existence of that market structure in the flour market can be related to the recent developments in Russia. According to information from the Russian union of flour producers in March 2020, grain producers refuse to supply grain to flour mills or make extra high grain prices for the domestic market due to the depreciation of the ruble and the increased export profitability. Moreover, the financial situation in the industry is further getting worse as since 2017 authorized banks stopped concessional lending to the most of flour producers. Now banks refuse to give money for flour mills due to their losses and insufficient level of pledge. That might result in a flour deficit in the Russian market.

Under the current circumstances government support is needed for flour export producers. First, government should compensate export logistics costs (their share in the total costs reaches up to 30%) as well as subsidize the grain price for processors. Among the measures of non-financial support, it is worth mention the promotion of the national brand of Russian flour on the foreign markets. Moreover, the industry needs government support in establishing contacts with key foreign enterprises and distributors. Important measures would be the reduction of logistical barriers for flour exporters. Second, in order to upgrade flour production facilities located near export logistics centers we recommend officials to provide flour processors with concessional loans.

The ECT coefficients representing the long-term relationship take higher value in the upward

Independent price variables	Dependent variable (ΔP_t^{out}) ΔFP_t		F-tests for linear restrictions		
	Split into positive and negative components		H_0: $\beta_j^+ = \beta_j^-$ $\quad$ $\sum_{j=1}^{m} \beta_j^+ = \sum_{j=1}^{n} \beta_j^-$		H_0: $\varphi^+ = \varphi^-$
	"+"	"-"			
Intercept (c)	0.029**			5.034**	1.562
ECT_{t-1}	-0.450***	-0.235**		(0.026)	(0.213)
ΔFP_{t-1}	0.258**	0.420***			
ΔFP_{t-2}	0.155	-0.083			
ΔFP_{t-3}	-0.023	0.144**			
ΔFP_{t-4}	0.032	-0.093			
ΔPP_{t-1}	0.345***	0.636**	0.446 (0.505)		
ΔPP_{t-2}	-0.280*	0.117	0.706 (0.402)		
ΔPP_{t-3}	0.004	0.015	0.001 (0.982)		
ΔPP_{t-4}	-0.101	0.667**	3.24* (0.073)		
Adj R^2	0.250		White's test, p-value 0.07		
DW-statistic	2.010		Normality (Doornik-Hansen) test, p-value 0.000		

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

Table 3: AVECM estimates and F-tests on the coefficients from the model.

direction than in the downward direction. It means that approximately 2.2 (1/0.45) months are required for the farm-gate prices to move towards their equilibrium level when the flour price increases, likewise it takes about 4.3 (1/0.235) months for adjustment towards equilibrium when there is a decrease in the processor prices. Consequently, farm-gate wheat prices converge to equilibrium more slowly in response to the decreases and more quickly to the increases in flour prices at the processor stage. However, the findings of the test indicate that null hypothesis of equilibrium adjustment path symmetry is not rejected.

Conclusion

The paper investigates the asymmetric effects of flour processor price changes on wheat price fluctuations by means of fitting linear AVECM model based on log-transformed monthly wheat and flour processor prices within the period from January 2000 until December 2019 in Russia. Moreover, we obtain long-run parameters of the flour price change effect on the wheat farm-gate price fluctuations. Our study provided empirical evidence as to the existence of long-run asymmetric price transmission within wheat-flour supply chain in Russia that is in line with vast literature on vertical price transmission. Understanding the asymmetric price transmission causes can have considerable welfare and policy implications. Significant reason of asymmetric price transmission on the Russian wheat market is imperfect competition among agents between farms and processing companies and the resulting market power. The grain producers oriented on huge export from Russia may use their market power and react more quickly to increased margins than to the reduced ones. Market power is also highly likely explanation for asymmetric price transmission in the long run. We exposed that wheat market conjuncture gave a dominant position for wheat producers and wholesalers over the wheat processors. The situation for flour producers is worsened by the existence of a big number of illegal processors, producing flour at low prices and selling it to small bakeries, as well as rather weak solvent consumer demand under steady reduction in real incomes. Under the circumstances, legal producers do not have the ability to raise prices, in contrast to wheat producers, and many of them have to operate approximately at the break-even level.

Follow-up study on the wheat-flour asymmetric price transmission can be extended with non-linear modeling and including retail sector in the analysis.

Acknowledgements

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