**Appendix**

**The influence of Russia’s 2010/11 wheat export ban on spatial market integration and transaction costs of grain markets**

Miranda Svanidze,\*a Linde Götz,a and Dmytro Serebrennikov b

a Leibniz Institute of Agricultural Development in Transition Economies (IAMO), 06120 Halle (Saale), Germany

b Teagasc Food Research Centre, Ashtown, Dublin, Ireland

\*Corresponding author, [svanidze@iamo.de](mailto:svanidze@iamo.de)

This appendix includes:

**Figure A1**.Map of crop-growing regions in Russia

**Figure A2**. Net domestic grain trade by railway in Russia

**Figure A3**. Wheat prices and regional trade by railway in Russia

**Figure A4**. Development of regional wheat prices in Russia during 2009-2012

**Appendix A**. TVECM model and estimation strategy

**Appendix B**. Results of the tests of unit root and cointegration

**Table A1**. Augmented Dickey-Fuller unit root test with break for prices in levels and first differences

**Table A2**. Gregory-Hansen cointegration test with regime shifts: sample 2009-2011 and 2010-2012

**Table A3**. Larsen test of threshold cointegration

**Table A4**. Wald test for the effects of export ban on price-transmission elasticities

**Table A5**. Estimated parameters of TVECM: 2009/10

**Table A6**. Estimated parameters of TVECM: 2010/11

**Table A7**. Estimated parameters of TVECM: 2011/12

**Table A8**. Wald test for the effects of export ban on threshold estimates

**Appendix C**. Half-lives in the middle regime

**Appendix D**. Posterior density of threshold parameter for price pairs containing North Caucasus

****

**Figure A1. Map of crop-growing regions in Russia**

*Source*: own elaboration.

**Figure A2. Net domestic grain trade by railway in Russia**

*Source*: Rosstat (2018), own elaboration.

(a) North Caucasus and Volga

(b) North Caucasus and West Siberia

**Figure A3. Wheat prices and regional trade by railway in Russia**

*Source*: reproduced from Götz, Djuric and Nivievskyi (2016).

**Figure A4. Development of regional wheat prices in Russia during 2009−2012**

*Note:* The bold area on the graph represents the period with restricted wheat exports from Russia.

*Source:* Russian Grain Union (2015), own elaboration.

**Appendix A. TVECM model and estimation strategy**

We examine price adjustment process using a non-linear three-regime TVECM with two thresholds (Greb et al. 2013). In the following TVECM model

denotes the vector of price changes, i.e. the difference between prices in periods and for both markets in question. Error correction terms, lagged residuals from equation (1), represent the price deviation from the long-run price equilibrium. It also serves as a threshold variable , which determines the state of the regime ; depending on the level of error correction term values relative to the thresholds. The short-run dynamics are characterized by the speed of adjustment parameter () and the coefficients of the price differences for each regime*,* . Lagged price variables are introduced to correct residual correlation up to the period . denotes a white-noise process with expected value and covariance matrix .

The three-regime TVECM is based on the assumption that two thresholds ( and ) exist corresponding to the costs of trade in both directions, i.e., from one market to the other and vice versa. We account for this asymmetry by allowing . Restrictions are imposed on threshold values such that captures trade reversals.

The adjustment parameter for market 1 and 2, respectively, with the expected value of and , measures how quickly deviations from the long-run equilibrium are eliminated by each of the prices in market 1 and 2. A smooth convergence to equilibrium is achieved by satisfying the condition that the total speed of adjustment varies between zero and one for each regime*,* (Greb et al. 2014). The total speed of adjustment () may differ between the regimes. In the outer regime, i.e. upper and lower regimes (), the speed of adjustment is faster due to the profitable trade arbitrage opportunities. However, we expect that price adjustment may not occur in the middle regime (2) as price deviations are smaller than trade costs, represented by the threshold values. Alternatively, slower price adjustment coefficients may be observed in the middle regime when price adjustment is induced by for example information flows or third markets (Stephens et al. 2012).

To identify optimal thresholds, we apply a regularized Bayesian estimator (Greb et al. 2014), which, in contrast to the traditional ordinary least squares and maximum likelihood estimators (Chan 1993; Hansen and Seo 2002), ensures that thresholds are well defined on the entire space of threshold parameters, with substantial outperformance in small samples (Greb et al. 2014). Compared to the profile likelihood technique, estimating thresholds using a regularized Bayesian estimator with a posterior density generates accurate estimates of transaction costs, especially in small samples (Greb et al. 2014). Reparameterization of model in equation (1) implies the following equation[[1]](#footnote-1)

,

where denotes the identity matrix; for observations at time points, an matrix , , is constructed by stacking rows of length . Matrix and , with , . In particular, is the th column of the matrix , and . Uniform priors for and , and normal priors for , , are introduced in the model.

It should be pointed out that alternative model frameworks exist allowing for varying transaction costs, such as the threshold autoregressive models (TAR) with time-varying thresholds and adjustment parameters (van Campenhout 2007) and TVECM models with the features of the smooth transition autoregressive (STAR) models (Hassouneh et al. 2012). While threshold models are fully parametric models, the semi-parametric generalized additive vector autoregressive model (VGAM) provided by Guney, Goodwin and Riquelme (2019) is a fully nonlinear modeling technique underlying the general model of spatial price behavior.

**Appendix B. Results of the tests of unit root and cointegration**

Results of the ADF-test with breaks suggest that all price series are nonstationary, i.e. are integrated of order one (Appendix, table A1). The Gregory-Hansen ADF test statistics show that in more than half of the cases, a regime shift in the cointegration relationships is identified (Appendix, table A2). In addition, occurrence of the break largely coincides with the beginning of the export ban in August 2010 in the 2009-2011 sample and the end of the export ban in June 2011 in the 2010-2012 sample (individual dates vary between May and November 2010 and between June and November 2011) for all price pairs. Hence, motivated by the results of the Gregory-Hansen test, we estimate the cointegrating equation and TVECM separately for the pre-ban and post-ban open trade and export ban periods. Results of the threshold cointegration test suggest that the null hypothesis of linear cointegration is rejected against a threshold cointegration with two thresholds at the 15% level of significance for all but four of the 15 price pairs during the 2009/10 free trade regime, for all but four of the 15 price pairs during the 2010/11 export ban and for all but six of the 15 price pairs during the 2011/12 free trade regime (Appendix, table A3).

**Table A1.** Augmented Dickey-Fuller unit root test with break for prices in levels and first differences

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Variable | Lags | Test-stat | P-values | Δ Variable | Lags | Test-stat | Test-stat |
| Central | 1 | -3.224 | 0.84 | Δ Central | 0 | -7.423\*\*\* | 0.01 |
| North Caucasus | 3 | -4.088 | 0.32 | Δ North Caucasus | 0 | -8,489\*\*\* | 0.01 |
| Black Earth | 1 | -3.637 | 0.61 | Δ Black Earth | 0 | -5.956\*\*\* | 0.01 |
| Volga | 3 | -3.310 | 0.80 | Δ Volga | 0 | -6.917\*\*\* | 0.01 |
| Ural | 2 | -3.414 | 0.74 | Δ Ural | 0 | -5.467\*\* | 0.01 |
| West Siberia | 2 | -3.052 | 0.90 | Δ West Siberia | 0 | -6.934\*\*\* | 0.01 |

Note: Lag length selection is based on Akaike Information Criterion. Deterministic component contains trend and intercept (intercept only) for prices in levels (first differences). Break specification is intercept only, break type is additive outlier, break date is selected by minimizing the Dickey-Fuller t-statistic. \*\*\* p<0.01, \*\* p<0.05, \* p<0.10.

**Table A2.** Gregory-Hansen cointegration test with regime shifts: sample 2009-2011 and 2010-2012

|  |  | 2009-2011 | | 2010-2012 | |
| --- | --- | --- | --- | --- | --- |
| Price pair | Distance (km) | ADF test statistic *a* | Break date | ADF test statistic *a* | Break date |
| Central – Black Earth | 526 | **-5.567\*\*\*** | Sep - 2010 | **-5.366\*\*** | Aug - 2011 |
| Central – Volga | 801 | **-5.139\*\*** | Jun - 2010 | -4.125 | Nov - 2011 |
| North Caucasus – Black Earth | 870 | -4.438 | Nov - 2010 | **-5.484\*\*\*** | Jun - 2011 |
| Black Earth – Volga | 1,035 | **-5.424\*\*** | Jun - 2010 | -3.643 | Sep - 2011 |
| Volga – Ural | 1,235 | -3.762 | May - 2010 | -4.497 | Sep - 2011 |
| North Caucasus – Central | 1,300 | **-5.373\*\*** | Nov - 2010 | **-5.520\*\*\*** | Jun - 2011 |
| Ural – West Siberia | 1,310 | **-5.517\*\*\*** | Sep - 2010 | **-5.452\*\*** | Jul - 2011 |
| North Caucasus – Volga | 1,708 | -4.110 | Nov - 2010 | **-4.962\*\*** | Jun - 2011 |
| Black Earth – Ural | 2,027 | **-5.285\*\*\*** | May - 2010 | **-4.792\*** | Sep - 2011 |
| Central – Ural | 2,044 | -4.492 | Jun - 2010 | **-5.090\*\*** | Sep - 2011 |
| Volga – West Siberia | 2,537 | -3.198 | Jul - 2010 | -4.556 | Mar - 2011 |
| North Caucasus – Ural | 2,682 | **-4.728\*** | Jul - 2010 | **-5.102\*\*** | Sep - 2011 |
| Black Earth – West Siberia | 3,329 | -4.365 | Jul - 2010 | -2.960 | Sep - 2011 |
| Central – West Siberia | 3,346 | -3.918 | May - 2010 | -3.336 | Sep - 2011 |
| North Caucasus – West Siberia | 3,984 | -4.496 | Jul - 2010 | **-5.415\*\*** | Jul - 2011 |

Note: Price pairs are sorted based on the distance between the administrative centers of the region in an ascending order. *a* Gregory-Hansen ADF critical values: -4.68, -4.95 and -5.47 at 10%, 5% and 1%, respectively. Lag length selection is based on Schwarz Information Criterion. Trimming parameter is 0.30. \*\*\* p<0.01, \*\* p<0.05, \* p<0.10.

**Table A3.** Larsen test of threshold cointegration

| Price pair | Larsen test (p-values) *a,* **†** | | |
| --- | --- | --- | --- |
| *2009/10* | *2010/11* | *2011/12* |
| Central – Black Earth | **0.060** | **0.032** | 0.270 |
| Central – Volga | **0.070** | **0.027** | **0.130** |
| Central – Ural | 0.210 | **0.080** | 0.180 |
| Central – West Siberia | 0.400 | 0.358 | 0.200 |
| North Caucasus – Central | **0.020** | **0.081** | 0.370 |
| North Caucasus – Black Earth | **0.080** | **0.047** | **0.070** |
| North Caucasus – Volga | **0.040** | **0.030** | **0.001** |
| North Caucasus – Ural | **0.010** | **0.130** | **0.020** |
| North Caucasus – West Siberia | **0.020** | **0.080** | 0.325 |
| Black Earth – Volga | **0.040** | 0.446 | 0.220 |
| Black Earth – Ural | **0.010** | 0.169 | **0.030** |
| Black Earth – West Siberia | **0.080** | **0.040** | **0.013** |
| Volga – Ural | 0.460 | 0.203 | **0.145** |
| Volga – West Siberia | **0.060** | **0.108** | **0.065** |
| Ural – West Siberia | 0.620 | **0.100** | **0.020** |

Note: *a* three-regime TVECM with two thresholds. **†** H0: linear cointegration | H1: threshold cointegration. Trimming parameter is 0.05, number of bootstrapping is set to 1000, type of bootstrapping is ‘fixed Regression’.

**Table A4.** Wald test for the effects of export ban on price transmission elasticities

| Price pairs | Distance (km) | Price transmission elasticity | | | Change 2010/11 vs 2009/10 | Change 2010/11 vs 2011/12 |
| --- | --- | --- | --- | --- | --- | --- |
| 2009/10 | 2010/11 | 2011/12 |
| Central – Black Earth | 526 | 0.94 | 0.917 | 0.989 | -0.023 | **0.072\*\*\*** |
| Central – Volga | 801 | 0.678 | 0.824 | 0.445 | 0.127 | **-0.379\*\*\*** |
| North Caucasus – Black Earth | 870 | 0.333 | 0.573 | 0.960 | **0.240\*\*** | **0.387\*\*\*** |
| Black Earth – Volga | 1,035 | 0.74 | 0.890 | 0.591 | 0.150 | **-0.299\*\*\*** |
| Volga – Ural | 1,235 | 0.677 | 0.844 | 0.196 | **0.167\*\*** | **-0.648\*\*\*** |
| North Caucasus – Central | 1,300 | 0.346 | 0.642 | 0.946 | **0.296\*\*\*** | **0.304\*\*\*** |
| Ural – West Siberia | 1,310 | 0.833 | 0.834 | 0.741 | 0.001 | -0.093 |
| North Caucasus – Volga | 1,708 | 0.267 | 0.543 | 0.661 | **0.277\*\*\*** | **0.118\*\*\*** |
| Black Earth – Ural | 2,027 | 0.469 | 0.760 | 0.114 | **0.291\*\*\*** | **-0.646\*\*** |
| Central – Ural | 2,044 | 0.432 | 0.670 | 0.185 | **0.267\*\*** | **-0.515\*** |
| Volga – West Siberia | 2,537 | 0.571 | 0.717 | 0.386 | **0.146\*\*** | **-0.331\*\*\*** |
| North Caucasus – Ural | 2,682 | 0.156 | 0.443 | 0.061 | **0.287\*\*\*** | -0.382 |
| Black Earth – West Siberia | 3,329 | 0.388 | 0.636 | 0.460 | **0.247\*\*** | -0.176 |
| Central – West Siberia | 3,346 | 0.358 | 0.589 | 0.512 | **0.231\*\*** | -0.077 |
| North Caucasus – West Siberia | 3,984 | 0.132 | 0.392 | 0.418 | **0.260\*\*\*** | 0.026 |

*Note*: We apply heteroscedasticity and autocorrelation consistent (HAC) covariance estimator to correct estimated standard errors for the accompanying autocorrelation and heteroscedasticity (Newey and West 1987). Price pairs are sorted based on the distance between the administrative centres of the region in an ascending order. \*\*\* p<0.01, \*\* p<0.05, \* p<0.10.

**Table A5.** Estimatedparameters of TVECM: 2009/10

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Price pair  (market 1 - market 2) | Thresholds | | Speed of adjustment parameters | | | Total adjustment *a* | | | | Half-lives | |
|  |  | lower  () | middle  () | upper  () | lower  () | middle  () | upper  () | outer  () | outer *b*  (weeks) | middle  (weeks) |
| Central - Black Earth | *-0.021* | *0.018* | -0.212 | -0.208† | -0.353\* | 0.340 | 0.572 | 0.733 | *0.537* | *0.9* | *0.8* |
| Black Earth - Central |  |  | 0.340\* | 0.364\*\* | 0.380\*\* |  |  |  |  |  |  |
| Central - Volga | *-0.013* | *0.003* | -0.077 | 0.088 | -0.183\*\* | 0.166 | - | 0.183 | *0.175* | *3.6* | *-* |
| Volga - Central |  |  | 0.166\* | 0.044 | 0.079 |  |  |  |  |  |  |
| Central -Ural | *-0.047* | *0.029* | -0.029 | -0.149† | -0.173\*\* | 0.310 | 0.328 | 0.273 | *0.292* | *2.0* | *1.7* |
| Ural - Central |  |  | 0.310\*\*\* | 0.179 | 0.100† |  |  |  |  |  |  |
| Central - West Siberia | *-0.062* | *0.021* | -0.039 | -0.102† | -0.166\*\* | 0.260 | 0.102 | 0.166 | *0.213* | *2.9* | *6.4* |
| West Siberia - Central |  |  | 0.260\*\* | 0.082 | -0.005 |  |  |  |  |  |  |
| North Caucasus - Black Earth | *-0.021* | *0.020* | -0.207\*\* | -0.207\*\* | -0.207\*\* | 0.207 | 0.207 | 0.207 | *0.207* | *3.0* | *3.0* |
| Black Earth - North Caucasus |  |  | -0.018 | -0.018 | -0.018 |  |  |  |  |  |  |
| North Caucasus - Central | *-0.030* | *0.020* | -0.300\*\* | -0.316\* | -0.168† | 0.300 | 0.430 | 0.168 | *0.234* | *2.6* | *1.2* |
| Central - North Caucasus |  |  | -0.153† | 0.114† | 0.031 |  |  |  |  |  |  |
| North Caucasus - Volga | *-0.038* | *0.018* | -0.169\* | -0.249\* | -0.171\*\* | 0.169 | 0.249 | 0.171 | *0.170* | *3.7* | *2.4* |
| Volga - North Caucasus |  |  | -0.055 | -0.108 | -0.064 |  |  |  |  |  |  |
| North Caucasus - Ural | *-0.062* | *0.028* | -0.153† | -0.062 | -0.087† | 0.153 | 0.208 | 0.087 | *0.120* | *5.4* | *3.0* |
| Ural - North Caucasus |  |  | 0.050 | 0.208\*\* | 0.085 |  |  |  |  |  |  |
| North Caucasus - West Siberia | *-0.047* | *0.027* | -0.220\*\* | -0.070 | -0.156\*\* | 0.22 | 0.229 | 0.156 | *0.188* | *3.3* | *2.7* |
| West Siberia - North Caucasus |  |  | 0.096 | 0.229\* | 0.069 |  |  |  |  |  |  |
| Black Earth - Volga | *-0.046* | *0.011* | -0.094\* | -0.146\*\* | -0.094\* | 0.094 | 0.146 | 0.094 | *0.094* | *7.0* | *4.4* |
| Volga - Black Earth |  |  | 0.022 | -0.003 | 0.022 |  |  |  |  |  |  |
| Black Earth - Ural | *-0.039* | *0.050* | 0.043 | 0.001 | -0.072 | 0.306 | 0.134 | 0.219 | *0.163* | *2.3* | *4.8* |
| Ural - Black Earth |  |  | 0.306\*\*\* | 0.134\* | 0.219\*\* |  |  |  |  |  |  |
| Black Earth - West Siberia | *-0.087* | *0.047* | 0.007 | -0.043 | -0.134† | 0.278 | - | 0.134 | *0.206* | *3* | *-* |
| West Siberia - Black Earth |  |  | 0.278\*\*\* | 0.022 | 0.043 |  |  |  |  |  |  |
| Volga - Ural | *-0.052* | *0.026* | 0.052 | 0.038 | 0.022 | 0.181 | 0.153 | 0.099 | *0.140* | *4.6* | *4.2* |
| Ural - Volga |  |  | 0.181\* | 0.153† | 0.099† |  |  |  |  |  |  |
| Volga - West Siberia | *-0.056* | *0.035* | -0.141† | -0.201\*\* | -0.288\*\*\* | 0.357 | 0.299 | 0.288 | *0.323* | *1.8* | *2.0* |
| West Siberia - Volga |  |  | 0.216† | 0.098† | -0.026 |  |  |  |  |  |  |
| Ural - West Siberia | *-0.027* | *0.012* | -0.206\* | -0.186† | -0.206† | 0.419 | 0.353 | 0.183 | *0.301* | *1.9* | *1.6* |
| West Siberia - Ural |  |  | 0.213† | 0.167† | 0.011 |  |  |  |  |  |  |

Note:*a*total adjustment in one regime is calculated as the sum of the absolute value of the respective regime-specific speed of adjustment parameters (with the expected sign only) of the TVECM significant at least 35% level. *b*half-lives in outer regime are calculated as the average of half-lives in the lower and upper regimes. - = not applicable. \*\*\* p<0.01, \*\* p<0.05, \* p<0.10, † p<0.35.

**Table A6.** Estimated parameters of TVECM: 2010/11

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Price pair  (market 1 - market 2) | | Thresholds | | | Speed of adjustment parameters | | | | | Total adjustment a | | | | Half-lives | |
|  |  | |  | lower  () | | middle  () | upper  () | lower  () | middle  () | | upper  () | outer  () | outer *b*  (weeks) | | middle  (weeks) |
| Central - Black Earth | *-0.022* | | *0.014* | 0.018 | | -0.437\* | -0.272 | 0.587 | 0.437 | | 0.301 | *0.442* | *1.2* | | *1.2* |
| Black Earth - Central |  | |  | 0.587\* | | 0.022 | 0.301† |  |  | |  |  |  | |  |
| Central - Volga | *-0.018* | | *0.008* | -0.690\*\*\* | | -0.290 | -0.168† | 0.690 | 0.290 | | 0.346 | *0.518* | *0.9* | | *2.0* |
| Volga - Central |  | |  | -0.142 | | 0.117 | 0.178† |  |  | |  |  |  | |  |
| Central -Ural | *-0.103* | | *0.031* | -0.416\*\*\* | | 0.035 | -0.191† | 0.416 | - | | 0.586 | *0.501* | *1.0* | | *-* |
| Ural - Central |  | |  | -0.017 | | 0.027 | 0.395\*\*\* |  |  | |  |  |  | |  |
| Central - West Siberia | *-0.105* | | *0.054* | -0.329\*\*\* | | 0.118\* | 0.158† | 0.329 | - | | 0.274 | *0.302* | *1.9* | | *-* |
| West Siberia - Central |  | |  | 0.040 | | 0.028 | 0.274\*\* |  |  | |  |  |  | |  |
| North Caucasus - Black Earth | *-0.090* | | *0.038* | -0.244\* | | -0.264\*\* | -0.217† | 0.244 | 0.339 | | 0.217 | *0.231* | *2.6* | | *1.7* |
| Black Earth - North Caucasus |  | |  | -0.014 | | -0.075† | 0.008 |  |  | |  |  |  | |  |
| North Caucasus - Central | *-0.048* | | *0.017* | -0.170 | | -0.065 | -0.176† | 0.170 | 0.430 | | 0.176 | *0.173* | *3.6* | | *1.2* |
| Central - North Caucasus |  | |  | -0.083 | | 0.306\*\* | -0.090 |  |  | |  |  |  | |  |
| North Caucasus - Volga | *-0.050* | | *0.007* | -0.261† | | -0.304\* | -0.231† | 0.261 | 0.304 | | 0.231 | *0.246* | *2.5* | | *1.9* |
| Volga - North Caucasus |  | |  | -0.145† | | -0.012 | -0.155† |  |  | |  |  |  | |  |
| North Caucasus - Ural | *-0.099* | | *0.085* | -0.323\*\*\* | | -0.323\*\*\* | -0.328\* | 0.323 | 0.323 | | 0.328 | *0.326* | *1.8* | | *1.8* |
| Ural - North Caucasus |  | |  | -0.036 | | -0.036 | -0.149† |  |  | |  |  |  | |  |
| North Caucasus - West Siberia | *-0.053* | | *0.075* | -0.372\*\*\* | | -0.305\*\* | -0.407\*\* | 0.372 | 0.305 | | 0.407 | *0.390* | *1.4* | | *1.9* |
| West Siberia - North Caucasus |  | |  | -0.032 | | -0.018 | -0.093 |  |  | |  |  |  | |  |
| Black Earth - Volga | *-0.039* | | *0.015* | 0.020 | | 0.002 | 0.020 | 0.352 | 0.350 | | 0.352 | *0.352* | *1.6* | | *1.6* |
| Volga - Black Earth |  | |  | 0.352\*\* | | 0.350\* | 0.352\*\* |  |  | |  |  |  | |  |
| Black Earth - Ural | *-0.049* | | *0.048* | -0.048 | | -0.212\* | -0.203† | - | 0.212 | | 0.379 | *0.379* | *1.5* | | *2.9* |
| Ural - Black Earth |  | |  | 0.028 | | 0.002 | 0.176† |  |  | |  |  |  | |  |
| Black Earth - West Siberia | *-0.107* | | *0.071* | -0.246\*\*\* | | 0.041 | -0.063 | 0.246 | 0.104 | | - | *0.246* | *2.5* | | *6.3* |
| West Siberia - Black Earth |  | |  | -0.150† | | 0.104† | 0.003 |  |  | |  |  |  | |  |
| Volga - Ural | *-0.107* | | *0.069* | -0.179\*\* | | -0.118\* | -0.234\* | 0.179 | 0.118 | | 0.234 | *0.207* | *3* | | *5.5* |
| Ural - Volga |  | |  | -0.006 | | 0.016 | -0.020 |  |  | |  |  |  | |  |
| Volga - West Siberia | *-0.105* | | *0.046* | -0.104† | | 0.041 | 0.105 | 0.104 | - | | 0.234 | *0.261* | *2.3* | | *-* |
| West Siberia - Volga |  | |  | 0.032 | | 0.061 | 0.418\*\*\* |  |  | |  |  |  | |  |
| Ural - West Siberia | *-0.061* | | *0.029* | 0.053 | | 0.039 | 0.039 | 0.318 | 0.300 | | 0.300 | *0.309* | *1.9* | | *1.9* |
| West Siberia - Ural |  | |  | 0.318\*\* | | 0.300\*\* | 0.300\*\* |  |  | |  |  |  | |  |

Note:*a*total adjustment in one regime is calculated as the sum of the absolute value of the respective regime-specific speed of adjustment parameters (with the expected sign only) of the TVECM significant at least 35% level. *b*half-lives in outer regime are calculated as the average of half-lives in the lower and upper regimes. - = not applicable. \*\*\* p<0.01, \*\* p<0.05, \* p<0.10, † p<0.35.

**Table A7.** Estimated parameters of TVECM: 2011/12

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Price pair  (market 1 - market 2) | Thresholds | | Speed of adjustment parameters | | | Total adjustment *a* | | | Half-lives | |
|  |  | lower | middle | upper | lower  () | middle  () | upper  () | outer *b*  (weeks) | middle  (weeks) |
| Central - Black Earth | *-0.025* | *0.009* | 1.372\*\*\* | -0.264 | -0.012 | - | - | 0.339 | *1.7* | *-* |
| Black Earth - Central |  |  | 2.027\*\*\* | 0.065 | 0.339† |  |  |  |  |  |
| Central - Volga | *-0.001* | *0.003* | -0.191† | -0.288† | -0.191† | 0.191 | 0.288 | 0.191 | *3.3* | *2.0* |
| Volga - Central |  |  | -0.173† | -0.344 | -0.173† |  |  |  |  |  |
| Central -Ural | *-0.267* | *0.062* | -0.387\*\*\* | 0.068 | 0.007 | 0.387 | 0.152 | 0.071 | *5.4* | *4.2* |
| Ural - Central |  |  | -0.015 | 0.152\*\*\* | 0.071† |  |  |  |  |  |
| Central - West Siberia | *-0.138* | *0.001* | 0.115 | 0.797\*\*\* | 0.056† | - | 0.469 | 0.144 | *4.5* | *1.1* |
| West Siberia - Central |  |  | 0.129 | 0.469\*\*\* | 0.144\* |  |  |  |  |  |
| North Caucasus - Black Earth | *-0.109* | *0.018* | 0.058 | -0.136† | 0.093 | 0.680 | 0.136 | 0.321 | *1.2* | *4.7* |
| Black Earth - North Caucasus |  |  | 0.680\*\*\* | -0.031 | 0.321\*\*\* |  |  |  |  |  |
| North Caucasus - Central | *-0.066* | *0.052* | -0.871\*\*\* | 0.076† | -1.223\*\*\* | 0.871 | 0.209 | - | *0.3* | *3.0* |
| Central - North Caucasus |  |  | -0.586\*\*\* | 0.209\*\*\* | -0.344† |  |  |  |  |  |
| North Caucasus - Volga | *-0.010* | *0.021* | -0.077† | 0.147 | -0.078† | 0.178 | 0.211 | 0.169 | *3.6* | *2.9* |
| Volga - North Caucasus |  |  | 0.101\* | 0.211† | 0.091† |  |  |  |  |  |
| North Caucasus - Ural | *-0.079* | *0.073* | -0.065† | -0.023 | -0.023 | 0.065 | - | - | *10.3* | *-* |
| Ural - North Caucasus |  |  | 0.018 | 0.028 | 0.028 |  |  |  |  |  |
| North Caucasus - West Siberia | *-0.177* | *0.057* | -0.027 | -0.043 | -0.043 | 0.216 | 0.133 | 0.133 | *3.8* | *4.8* |
| West Siberia - North Caucasus |  |  | 0.216\*\*\* | 0.133\*\* | 0.133\*\* |  |  |  |  |  |
| Black Earth - Volga | *-0.016* | *0.015* | -0.169† | -0.169† | -0.186† | 0.169 | 0.169 | 0.186 | *3.6* | *3.7* |
| Volga - Black Earth |  |  | -0.327\* | -0.327\* | -0.395\*\*\* |  |  |  |  |  |
| Black Earth - Ural | *-0.100* | *0.050* | -0.115\*\* | 0.150\* | 0.035 | 0.265 | 0.132 | 0.076 | *5.5* | *4.9* |
| Ural - Black Earth |  |  | 0.150\*\*\* | 0.132\* | 0.076† |  |  |  |  |  |
| Black Earth - West Siberia | *-0.183* | *0.001* | 0.031 | 0.469\*\*\* | 0.065† | 0.252 | 0.483 | 0.185 | *2.9* | *1.1* |
| West Siberia - Black Earth |  |  | 0.252† | 0.483\*\*\* | 0.185\*\* |  |  |  |  |  |
| Volga - Ural | *-0.092* | *0.021* | -0.174† | 0.020 | 0.020 | 0.373 | - | - | *1.5* | *-* |
| Ural - Volga |  |  | 0.198\*\* | 0.021 | 0.021 |  |  |  |  |  |
| Volga - West Siberia | *-0.168* | *0.004* | 0.015 | 0.205† | -0.048 | 0.621 | 0.418 | 0.395 | *1.0* | *1.3* |
| West Siberia - Volga |  |  | 0.621\*\*\* | 0.418\*\*\* | 0.395\*\*\* |  |  |  |  |  |
| Ural - West Siberia | *-0.040* | *0.053* | -0.227\*\*\* | -0.227\*\*\* | -0.229\*\*\* | 0.227 | 0.227 | 0.293 | *2.3* | *2.7* |
| West Siberia - Ural |  |  | -0.309\*\*\* | -0.309\*\*\* | -0.293\*\*\* |  |  |  |  |  |

Note:*a*total adjustment in one regime is calculated as the sum of the absolute value of the respective regime-specific speed of adjustment parameters (with the expected sign only) of the TVECM significant at least 35% level. *b*half-lives in outer regime are calculated as the average of half-lives in the lower and upper regimes. - = not applicable. \*\*\* p<0.01, \*\* p<0.05, \* p<0.10, † p<0.35.

**Appendix C. Half-lives in the middle regime**

**Figure C1. Half-lives in the middle regime: pre-ban, export ban and post-ban periods**

*Note*: (b): Price pairs are presented on the x-axis by distance between markets, varying between 526 km and 3,984 km (see Table A4 in the Appendix for further details on distances).

*Source:* own calculations and elaboration.

Similar to the outer regimes, we find half-lives for the middle regime increasing during the export ban period compared to the pre-ban period, and half-lives increasing again in the post-ban period in general (Figure C1). In particular, we find half-life smaller and such price adjustment faster in the ban period compared to the pre-ban period for 7 out of 15 price pairs and equal between the periods for one case. Also, half-life estimates suggest slower price adjustment during the post-ban period compared to the export ban period for 7 price pairs and price adjustment even no longer observed for 3 price pairs in the post-ban period. One extreme case is the price pair North Caucasus and Ural for which a relatively large half-life amounting to 6.3 is observed during the export ban, while no price adjustment is observed neither in the per-ban and post-ban period.

However, regarding the size of the half-lives in the middle regime compared to the outer regimes, we find for 2009/10 for 3 out of the 15 price pairs the half-lives larger in the middle regime compared to the outer regimes, for 2 price pairs price adjustment is not at all observed in the middle regime and for 1 price pair half-lives are of equal size. For 2010/11, we find for 5 out of the 15 price pairs half-lives in the middle regime larger compared to the outer regime, for 3 price pairs no price adjustment is observed in the middle regime and for 4 price pairs half-lives are of equal size. For the 2011/12 post-ban period, we find for 6 out of 15 price pairs half-lives larger in the middle regime compared to the outer regimes and for 3 price pairs no price adjustment is observed in the middle regime. This result only partially fits with the assumption that price shocks are not at all or only at a lower speed corrected in the middle regime compared to the outer regimes.

**Table A8.** Wald test for the effects of export ban on threshold estimates

| Price pairs | Distance (km) | Threshold lower () | | | | |  | Threshold upper () | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 2009/10 | 2010/11 | 2011/12 | P-value  (2009/10 vs 2010/11) | P-value  (2010/11 vs 2011/12) |  | 2009/10 | 2010/11 | 2011/12 | P-value  (2009/10 vs 2010/11) | P-value  (2010/11 vs 2011/12) |
| Central – Black Earth | 526 | -0.021 | -0.022 | -0.025 | 0.960 | 0.595 |  | 0.018 | 0.014 | 0.009 | 0.876 | 0.669 |
| Central – Volga | 801 | -0.013 | -0.018 | -0.001 | 0.612 | **0.001** |  | 0.003 | 0.008 | 0.003 | 0.689 | 0.513 |
| North Caucasus – Black Earth | 870 | -0.021 | -0.090 | -0.109 | **0.044** | 0.641 |  | 0.020 | 0.038 | 0.018 | 0.162 | **0.139** |
| Black Earth – Volga | 1,035 | -0.046 | -0.039 | -0.016 | 0.693 | **0.132** |  | 0.011 | 0.015 | 0.015 | 0.780 | 0.991 |
| Volga – Ural | 1,235 | -0.052 | -0.107 | -0.092 | **0.124** | 0.732 |  | 0.026 | 0.069 | 0.021 | **0.099** | 0.301 |
| North Caucasus – Central | 1,300 | -0.030 | -0.048 | -0.066 | 0.214 | 0.259 |  | 0.020 | 0.017 | 0.052 | 0.771 | 0.256 |
| Ural – West Siberia | 1,310 | -0.027 | -0.061 | -0.040 | 0.312 | 0.611 |  | 0.012 | 0.029 | 0.053 | 0.463 | 0.622 |
| North Caucasus – Volga | 1,708 | -0.038 | -0.050 | -0.010 | 0.345 | **0.005** |  | 0.019 | 0.007 | 0.021 | 0.432 | 0.308 |
| Black Earth – Ural | 2,027 | -0.039 | -0.049 | -0.100 | 0.773 | 0.267 |  | 0.050 | 0.048 | 0.050 | 0.935 | 0.966 |
| Central – Ural | 2,044 | -0.047 | -0.103 | -0.267 | **0.098** | **0.002** |  | 0.029 | 0.031 | 0.062 | 0.961 | 0.527 |
| Volga – West Siberia | 2,537 | -0.056 | -0.105 | -0.168 | **0.121** | 0.340 |  | 0.035 | 0.046 | 0.004 | 0.666 | **0.007** |
| North Caucasus – Ural | 2,682 | -0.062 | -0.099 | -0.079 | 0.357 | 0.780 |  | 0.028 | 0.085 | 0.073 | **0.025** | 0.803 |
| Black Earth – West Siberia | 3,329 | -0.087 | -0.107 | -0.183 | 0.661 | **0.045** |  | 0.047 | 0.071 | 0.001 | 0.462 | **0.001** |
| Central – West Siberia | 3,346 | -0.062 | -0.105 | -0.138 | **0.061** | 0.250 |  | 0.021 | 0.054 | 0.001 | 0.228 | **0.015** |
| North Caucasus – West Siberia | 3,984 | -0.047 | -0.053 | -0.177 | 0.795 | **0.016** |  | 0.037 | 0.075 | 0.057 | **0.103** | 0.384 |

*Note*: Price pairs are sorted based on the distance between the administrative centers of the region in an ascending order.

**Appendix D. Posterior density of threshold parameter for price pairs containing North Caucasus**

**North Caucasus – Black Earth**

|  |  |  |  |
| --- | --- | --- | --- |
|  | 2009-10 | 2010-11 | 2011-12 |
| Lower threshold |  |  |  |
| Upper threshold |  |  |  |

*Note*: threshold parameter is presented on the x-axis. Log posterior density is presented on the y-axis. Dashed vertical line shows a posterior median representing “optimal” threshold estimate of the model.

**North Caucasus – Central**

|  |  |  |  |
| --- | --- | --- | --- |
|  | 2009-10 | 2010-11 | 2011-12 |
| Lower threshold |  |  |  |
| Upper threshold |  |  |  |

*Note*: threshold parameter is presented on the x-axis. Log posterior density is presented on the y-axis. Dashed vertical line shows a posterior median representing “optimal” threshold estimate of the model.

**North Caucasus – Volga**

|  |  |  |  |
| --- | --- | --- | --- |
|  | 2009-10 | 2010-11 | 2011-12 |
| Lower threshold |  |  |  |
| Upper threshold |  |  |  |

*Note*: threshold parameter is presented on the x-axis. Log posterior density is presented on the y-axis. Dashed vertical line shows a posterior median representing “optimal” threshold estimate of the model.

**North Caucasus – Ural**

|  |  |  |  |
| --- | --- | --- | --- |
|  | 2009-10 | 2010-11 | 2011-12 |
| Lower threshold |  |  |  |
| Upper threshold |  |  |  |

*Note*: threshold parameter is presented on the x-axis. Log posterior density is presented on the y-axis. Dashed vertical line shows a posterior median representing “optimal” threshold estimate of the model.

**North Caucasus – West Siberia**

|  |  |  |  |
| --- | --- | --- | --- |
|  | 2009-10 | 2010-11 | 2011-12 |
| Lower threshold |  |  |  |
| Upper threshold |  |  |  |

*Note*: threshold parameter is presented on the x-axis. Log posterior density is presented on the y-axis. Dashed vertical line shows a posterior median representing “optimal” threshold estimate of the model.

**References**

Chan, K. S. 1993. Consistency and limiting distribution of the least squares estimator of a threshold autoregressive model. *The Annals of Statistics* 21: 520–533.

Götz, L., I. Djuric, and O. Nivievskyi. 2016. Regional price effects of extreme weather events and wheat export controls in Russia and Ukraine. *Journal of Agricultural Economics* 67: 741–763.

Greb, F., Krivobokova, T., A. Munk, and S. von Cramon-Taubadel. 2014. Regularized Bayesian estimation of generalized threshold regression models. *Bayesian Analysis* 9: 171–196.

Greb, F., von Cramon-Taubadel, S., T. Krivobokova, and A. Munk. 2013. The estimation of threshold models in price transmission analysis. *American Journal of Agricultural Economics* 95: 900–916.

Guney, S., Goodwin, B. K., and A. Riquelme. 2019. Semi-Parametric Generalized Additive Vector Autoregressive Models of Spatial Basis Dynamics. *American Journal of Agricultural Economics* 101 (2): 541-562.

Hansen, B., and B. Seo. 2002. Testing for two-regime threshold co-integration in vector error-correction models. *Journal of Econometrics* 110: 293–318.

Hassouneh, I., von Cramon-Taubadel, S., Serra, T., and J. M. Gil. 2012. Recent developments in the econometric analysis of price transmission. Transparency of Food Pricing Working Paper.

Newey, W., and K. West. 1987. Hypothesis testing with efficient method of moments estimation. *International Economic Review* 28: 777–787.

Rosstat. 2018. Federal State Statistics Service. [www.gks.ru](http://www.gks.ru).

Stephens, E. C., Mabaya, E., S. von Cramon-Taubadel, and C. B. Barrett. 2012. Spatial price adjustment with and without trade. *Oxford Bulletin of Economics and Statistics* 74: 453–469.

Van Campenhout, B. 2007. Modelling trends in food market integration: Method and an application to Tanzanian maize markets. *Food Policy* 32 (3): 112-127.

1. For the step-by-step derivation of the equation, see Greb et al. (2013). [↑](#footnote-ref-1)