**Supplementary information**

**Spatial market efficiency of grain markets in Russia and global food security: Evidence from a comparison with the USA**

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**Table S1.** Variation of grain production, relative to the last 3-years-average (%)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Economic regions/ Federal states | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| *Russia, wheat* |
|  North Caucasus | 107 | 104 | 108 | 68 | 102 | 131 | 135 |
|  Central | 159 | 81 | 79 | 97 | 137 | 127 | 122 |
|  Black Earth | 136 | 46 | 86 | 96 | 163 | 131 | 106 |
|  Volga | 109 | 34 | 81 | 84 | 99 | 96 | 134 |
|  West Siberia | 140 | 86 | 96 | 46 | 113 | 97 | 125 |
|  Ural | 87 | 38 | 144 | 61 | 93 | 95 | 141 |
| *USA, corn* |
|  Iowa | 111 | 92 | 104 | 81 | 101 | 111 | 118 |
|  Illinois | 99 | 90 | 95 | 65 | 122 | 132 | 105 |
|  Nebraska | 117 | 99 | 104 | 85 | 113 | 108 | 113 |
|  Minnesota | 109 | 108 | 97 | 110 | 100 | 91 | 111 |
|  South Dakota | 150 | 93 | 105 | 83 | 137 | 119 | 113 |
|  Kansas | 134 | 109 | 81 | 70 | 107 | 127 | 120 |
|  Missouri | 111 | 86 | 88 | 64 | 135 | 183 | 100 |

Source: reproduced from Götz *et al*. (2016) for Russia and own calculations for the USA (USDA-ERS, 2017).

**Table S2.** Augmented Dickey-Fuller test for prices in levels and first differences

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| price series | determ.component | lags | test-stat. | Δ price series | determ. component | lags | test-stat. |
| *Russia (interregional analysis)*  |
| Central | Constant & trend | 3 | -2.924 | Δ Central | None | 0 | -3.396\*\*\* |
| N. Caucasus | Constant  | 1 | -1.581 | Δ N. Caucasus | None | 0 | -7.305\*\*\* |
| Black Earth | None | 1 | -0.755 | Δ Black Earth | None | 0 | -2.823\*\*\* |
| Volga | Constant  | 4 | -2.252 | Δ Volga | None | 0 | -4.086\*\*\* |
| Urals | Constant  | 1 | -2.170 | Δ Urals | None | 0 | -2.793\*\*\* |
| W. Siberia | Constant  | 0 | -2.211 | Δ W. Siberia | None | 1 | -2.081\*\*\* |
| *USA (interregional analysis)* |
| Arkansas | Constant | 0 | -1.925 | Δ Arkansas | None | 0 | -7.579\*\*\* |
| California | Constant | 0 | -1.893 | Δ California | None | 0 | -7.437\*\*\* |
| Colorado | Constant | 0 | -1.690 | Δ Colorado | None | 0 | -7.157\*\*\* |
| Illinois | Constant | 0 | -2.376 | Δ Illinois | None | 0 | -7.289\*\*\* |
| Iowa | Constant | 0 | -2.448 | Δ Iowa | None | 0 | -9.139\*\*\* |
| Kansas | Constant | 0 | -1.793 | Δ Kansas | None | 0 | -7.218\*\*\* |
| Minnesota | Constant | 0 | -1.799 | Δ Minnesota | None | 0 | -7.570\*\*\* |
| Missouri | Constant | 0 | -1.857 | Δ Missouri | None | 0 | -7.538\*\*\* |
| Nebraska | Constant | 0 | -1.884 | Δ Nebraska | None | 0 | -7.589\*\*\* |
| Oklahoma | Constant | 0 | -1.802 | Δ Oklahoma | None | 0 | -7.248\*\*\* |
| Oregon | Constant | 0 | -1.696 | Δ Oregon | None | 0 | -7.182\*\*\* |
| S. Dakota | Constant | 0 | -2.400 | Δ S. Dakota | None | 0 | -8.358\*\*\* |
| Texas | Constant | 0 | -1.695 | Δ Texas | None | 0 | -7.252\*\*\* |
| Virginia | Constant | 0 | -1.996 | Δ Virginia | None | 0 | -7.312\*\*\* |
| Washington | Constant | 0 | -1.642 | Δ Washington | None | 0 | -6.579\*\*\* |
| Wyoming | Constant | 0 | -0.693 | Δ Wyoming | None | 0 | -7.002\*\*\* |
| *Black Earth (intraregional analysis)* |
| Belgorod | None | 1 | 1.314 | Δ Adygea | None | 0 | -4.836\*\*\* |
| Kursk | None | 1 | 1.795 | Δ Krasnodar | None | 0 | -5.472\*\*\* |
| Lipetsk | None | 1 | 0.517 | Δ Rostov | None | 0 | -4.419\*\*\* |
| Tambov | None | 3 | 1.134 | Δ Stavropol | None | 2 | -2.467\*\*\* |
| Voronezh | Constant | 1 | -1.891 | Δ Voronezh | None | 0 | -4.659\*\*\* |
| *West Siberia (intraregional analysis)* |
| Altai | Constant | 1 | -2.237 | Δ Altai | None | 0 | -3.696\*\*\* |
| Kemerovo | Constant | 1 | -2.395 | Δ Kemerovo | None | 0 | -3.926\*\*\* |
| Novosibirsk | Constant | 0 | -1.439 | Δ Novosibirsk | None | 0 | -5.364\*\*\* |
| Omsk | Constant | 0 | -1.431 | Δ Omsk | None | 1 | -4.599\*\*\* |
| Tomsk | Constant | 1 | -2.074 | Δ Tomsk | None | 1 | -3.765\*\*\* |
| Tyumen | Constant | 0 | -1.806 | Δ Tyumen | None | 1 | -5.063\*\*\* |
| *Iowa (intraregional analysis)* |
| Cedar Rapids | Constant  | 0 | -2.140 | Δ Cedar Rapids | None | 0 | -10.444\*\*\* |
| Clinton | Constant  | 0 | -1.163 | Δ Clinton | None | 0 | -9.478\*\*\* |
| Davenport | Constant  | 0 | -2.275 | Δ Davenport | None | 0 | -9.609\*\*\* |
| Eddyville | Constant & trend | 0 | -2.928 | Δ Eddyville | None | 0 | -11.082\*\*\* |
| Emmetsburg | Constant  | 0 | -1.895 | Δ Emmetsburg | None | 0 | -10.301\*\*\* |
| Keokuk | Constant  | 0 | -2.412 | Δ Keokuk | None | 0 | -9.951\*\*\* |
| Muscatine | Constant  | 0 | -2.263 | Δ Muscatine | None | 0 | -9.335\*\*\* |
| W. Burlington | Constant  | 0 | -2.118 | Δ W. Burlington | None | 0 | -9.464\*\*\* |
| (*continued*) |
| **Table S2.** (*continued*) |
| price series | determ.component | lags | test-stat. | Δ price series | determ. component | lags | test-stat. |
| *North Carolina (intraregional analysis)* |
| Candor | Constant  | 0 | -1.667 | Δ Candor | None | 0 | -10.105\*\*\* |
| Cofield | Constant  | 0 | -1.763 | Δ Cofield | None | 0 | -9.559\*\*\* |
| Creswell | Constant  | 0 | -2.312 | Δ Creswell | None | 0 | -11.270\*\*\* |
| Laurinburg | Constant  | 0 | -1.817 | Δ Laurinburg | None | 0 | -9.200\*\*\* |
| Roaring River | Constant  | 0 | -1.588 | Δ Roaring River | None | 0 | -10.089\*\*\* |
| Statesville | Constant  | 0 | -1.861 | Δ Statesville | None | 0 | -10.143\*\*\* |

Note: Lag length selection is based on Schwarz Information Criterion. \* p<0.10, \*\* p<0.05, \*\*\* p<0.01.

**Table S3.** Tests of cointegration: interregional analysis

|  |  |  |  |
| --- | --- | --- | --- |
| price pair | Hansen & Seo test (2002)**†,** *a*  | Larsen test (2012)**†,** *b*  | Johansen test (1988) *c* |
| sup-Waldtest statistic | 5% cr. value | p-value | trace test statistic  | p-value |
| *Russia* |
| Central – Black Earth | 11.111 | 18.398 | 0.06 | 21.606\*\* **/** 4.031 | 0.033 **/** 0.408 |
| Central – Volga | 17.262 | 18.596 | 0.07 | 34.094\*\*\* **/** 5.105 | 0.001 / 0.272 |
| Central – Urals | 20.363\*\*\* | 18.566 | 0.21 | 27.700\*\*\* **/** 7.133 | 0.004 / 0.120 |
| Central – W. Siberia | 14.133\*\* | 13.109 | 0.40 | 22.342\*\* **/** 6.243 | 0.026 / 0.173 |
| N. Caucasus – Central | 21.037\*\* | 19.054 | 0.02 | 14.645 **/** 3.468 | 0.248 / 0.497 |
| N. Caucasus – Black Earth | 13.932\* | 14.769 | 0.08 | 37.811\*\*\* **/** 4.477 | 0.001 / 0.346 |
| N. Caucasus – Volga | 21.666\*\*\* | 18.271 | 0.04 | 27.197\*\* **/** 8.189 | 0.034 / 0.237 |
| N. Caucasus – Urals | 24.227\*\*\* | 19.072 | 0.01 | 16.076\*\* **/** 0.598 | 0.041 / 0.439 |
| N. Caucasus – W. Siberia | 20.543\*\* | 19.377 | 0.02 | 36.835\*\*\* **/** 4.320 | 0.001 / 0.367 |
| Black Earth – Volga | 24.383\* | 05.088 | 0.04 | 20.484\*\* **/** 4.454 | 0.047 / 0.349 |
| Black Earth – Urals | 25.332\*\*\* | 24.907 | 0.01 | 18.413\* **/** 2.392 | 0.088 / 0.699 |
| Black Earth – W. Siberia | 15.223\* | 16.237 | 0.08 | 26.237\*\*\* **/** 4.579 | 0.007 / 0.333 |
| Volga – Urals | 17.746\* | 18.451 | 0.46 | 35.220\*\*\* **/** 6.298 | 0.001 / 0.169 |
| Volga – W. Siberia | 12.149\* | 13.296 | 0.06 | 25.246\*\*\* **/** 7.248 | 0.009 / 0.114 |
| Urals – W. Siberia | 18.002\* | 18.528 | 0.62 | 17.093 **/** 6.817 | 0.129 / 0.136 |
| *USA* |
| Arkansas – Illinois  | 11.387 | 15.980 | 0.70 | 9.528 / 4.674 |  0.685/ 0.321 |
| Arkansas – Iowa | 16.040\*\* | 15.947 | 0.05 | 16.436\*\* / 3.528\*  | 0.036/ 0.060 |
| Arkansas – Kansas | 9.476 | 16.519 | 0.98 | 8.789 / 3.297 | 0.755 / 0.526 |
| Arkansas – Minnesota | 12.576 | 16.233 | 0.34 | 11.386 / 3.629 | 0.505 / 0.470 |
| Arkansas – Missouri | 14.236\*\* | 16.049 | 0.58 | 21.525\*\* / 9.164 | 0. 033/ 0.543 |
| Arkansas – Nebraska | 16.593\*\* | 16.349 | 0.01 | 9.898 / 0.001 | 0.123 / 0.972 |
| Arkansas – S. Dakota | 7.041 | 16.557 | 0.26 | 10.643\* / 0.001 | 0.094 / 0.997 |
| California – Illinois | 12.655\* | 13.636 | 0.03 | 24.530\*\*\*/ 4.142 | 0.012 / 0.391 |
| California – Iowa | 15.553\* | 17.087 | 0.41 | 31.955\*\*\*/ 3.468 | 0.001 / 0.497 |
| California – Kansas | 14.403 | 16.642 | 0.21 | 20.587\*\*/ 3.186 | 0.045 / 0.546 |
| California – Minnesota | 17.510\*\* | 16.011 | 0.01 | 23.688\*\*\*/ 3.018 | 0.016/ 0.577 |
| (*continued*) |
| **Table S3.** (*continued*) |
| price pair | Hansen & Seo test (2002)**†,** *a*  | Larsen test (2012)**†,** *b*  | Johansen test (1988) *c* |
| sup-Waldtest statistic | 5% cr. value | p-value | trace test statistic  | p-value |
| California – Missouri | 12.342\* | 13.603 | 0.26 | 30.757\*\*\*/ 2.906 | 0.001/0.598 |
| California – Nebraska | 20.138\*\* | 18.474 | 0.12 | 29.767\*\*\*/3.097 | 0.001/ 0.562 |
| California – S. Dakota | 11.643 | 14.028 | 0.01 | 32.662\*\*\*/ 3.516 | 0.001/0.488 |
| Colorado – Illinois | 10.432 | 13.864 | 0.09 | 19.105\*\*/ 2.434 | 0.013/ 0.118 |
| Colorado – Iowa | 11.573 | 13.418 | 0.28 | 26.259\*\*\*/ 2.519 | 0.001/ 0.112 |
| Colorado – Kansas | 9.499 | 13.660 | 0.21 | 15.657\*\*/ 5.172\*\*\* | 0.047/ 0.022 |
| Colorado – Minnesota | 12.088 | 16.271 | 0.12 | 8.843/ 2.741\* | 0.380/ 0.097 |
| Colorado – Missouri | 15.229\* | 15.647 | 0.22 | 14.072\*/ 3.073\* | 0.081/ 0.079 |
| Colorado – Nebraska | 9.4381 | 13.448 | 0.85 | 6.240/ 1.953 | 0.667/ 0.162 |
| Colorado – S. Dakota | 12.891\* | 13.665 | 0.24 | 21.907\*\*\*/ 3.841 | 0.004/ 0.106 |
| Oklahoma – Illinois | 12.826\* | 13.925 | 0.06 | 24.428\*\*/ 3.562 | 0.012/ 0.481 |
| Oklahoma – Iowa | 14.715\*\* | 13.729 | 0.05 | 29.764\*\*/ 3.366 | 0.002/ 0.514 |
| Oklahoma – Kansas | 15.683\* | 16.575 | 0.16 | 16.399\*\*/ 3.434\* | 0.036/ 0.063 |
| Oklahoma – Minnesota | 20.062\*\*\* | 15.917 | 0.01 | 12.074/ 3.231\* | 0.153/ 0.072 |
| Oklahoma – Missouri | 17.247\*\* | 15.919 | 0.07 | 17.505\*\*/ 3.841\* | 0.024/ 0.071 |
| Oklahoma – Nebraska | 14.978 | 16.306 | 0.31 | 8.888/ 3.271\* | 0.375/ 0.070 |
| Oklahoma – S. Dakota | 12.941\* | 13.593 | 0.08 | 17.751\*\*/ 3.186\* | 0.022/ 0.074 |
| Oregon – Illinois | 18.956\*\*\* | 13.741 | 0.01 | 25.721\*\*\*/ 6.552 | 0.008/ 0.152 |
| Oregon – Iowa | 17.515\* | 18.234 | 0.10 | 25.060\*\*/ 3.042 | 0.010/ 0.572 |
| Oregon – Kansas | 16.902\*\*\* | 13.892 | 0.02 | 20.637\*\*/ 7.298 | 0.044/ 0.106 |
| Oregon – Minnesota | 18.092\*\* | 16.285 | 0.01 | 14.581/ 3.248 | 0.251/ 0.535 |
| Oregon – Missouri | 11.520 | 13.244 | 0.24 | 23.816\*\*/ 3.558 | 0.015/ 0.481 |
| Oregon – Nebraska | 10.207 | 13.271 | 0.22 | 10.411\*/ 0.008 | 0.102/ 0.938 |
| Oregon – S. Dakota | 17.228\*\*\* | 13.601 | 0.01 | 21.960\*\*\*/ 2.844\* | 0.004/ 0.091 |
| Texas – Illinois | 14.871\*\* | 14.115 | 0.05 | 16.911\*\*/ 15.494 | 0.030/ 0.158 |
| Texas – Iowa | 12.696\* | 13.657 | 0.01 | 11.080\*/ 0.005 | 0.080/ 0.950 |
| Texas – Kansas | 13.235\* | 14.024 | 0.26 | 33.326\*\*\*/ 2.475 | 0.001/ 0.115 |
| Texas – Minnesota | 10.946 | 13.589 | 0.24 | 10.598\*/ 0.051 | 0.095/ 0.852 |
| Texas – Missouri | 17.050\*\* | 16.727 | 0.25 | 20.667\*\*\*/ 2.874\* | 0.007/ 0.090 |
| Texas – Nebraska | 15.481\*\* | 13.427 | 0.15 | 10.140/ 3.006\* | 0.270/ 0.082 |
| Texas – S. Dakota | 11.019 | 16.406 | 0.37 | 19.959\*\*\*/ 2.704 | 0.009/ 0.100 |
| Virginia – Illinois | 11.131 | 13.629 | 0.17 | 19.653\*/ 3.633 | 0.060/ 0.469 |
| Virginia – Iowa | 9.079 | 13.096 | 0.13 | 34.631\*\*\*/ 4.825 | 0.001/ 0.303 |
| Virginia – Kansas | 12.274 | 16.262 | 0.43 | 22.076\*\*/ 5.625 | 0.027/ 0.221 |
| Virginia – Minnesota | 10.385 | 13.886 | 0.32 | 21.934\*\*/ 6.740 | 0.029/ 0.140 |
| Virginia – Missouri | 13.757\*\* | 13.116 | 0.32 | 31.974\*\*\*/ 3.957 | 0.001/ 0.418 |
| Virginia – Nebraska | 9.624 | 13.629 | 0.37 | 10.516\*/ 0.023 | 0.098/ 0.899 |
| Virginia – S. Dakota | 11.328 | 13.578 | 0.01 | 13.822\*\*/ 0.030 | 0.027/ 0.885 |
| Washington – Illinois | 12.481\* | 13.412 | 0.03 | 27.240\*\*\*/ 4.474 | 0.004/ 0.346 |
| Washington – Iowa | 14.026\* | 14.300 | 0.20 | 33.120\*\*\*/ 2.623 | 0.001/ 0.653 |
| Washington – Kansas | 13.458 | 15.638 | 0.25 | 21.222\*\*/ 4.293 | 0.036/ 0.370 |
| Washington – Minnesota | 14.191\*\* | 13.198 | 0.24 | 14.326/ 2.656 | 0.267/ 0.646 |
| Washington – Missouri | 16.208\*\* | 15.956 | 0.01 | 31.900\*\*\*/ 3.038 | 0.001/ 0.573 |
| Washington – Nebraska | 9.983 | 14.110 | 0.70 | 12.671/ 2.669 | 0.390/ 0.644 |
| Washington – S. Dakota | 12.162 | 13.877 | 0.27 | 22.459\*\*/ 2.559 | 0.024/ 0.665 |
| Wyoming – Illinois | 10.723 | 13.364 | 0.36 | 21.784\*\*/ 9.164 | 0.030/ 0.291 |
| Wyoming – Iowa | 9.385 | 13.961 | 0.49 | 22.083\*\*/ 3.140 | 0.027/ 0.554 |
| (*continued*) |
| **Table S3.** (*continued*) |
| price pair | Hansen & Seo test (2002)**†,** *a*  | Larsen test (2012)**†,** *b*  | Johansen test (1988) *c* |
| sup-Waldtest statistic | 5% cr. value | p-value | trace test statistic  | p-value |
| Wyoming – Kansas | 11.594 | 14.075 | 0.22 | 20.220\*\*/ 7.547 | 0.050/ 0.100 |
| Wyoming – Minnesota | 5.873 | 8.959 | 0.92 | 10.641/ 3.446 | 0.577/ 0.500 |
| Wyoming – Missouri | 15.099\*\* | 13.511 | 0.08 | 15.860\*\*/ 3.834\*\* | 0.044/ 0.050 |
| Wyoming – Nebraska | 10.925 | 13.366 | 0.46 | 11.351/ 3.514\* | 0.190/ 0.060 |
| Wyoming – S. Dakota | 12.893 | 13.762 | 0.12 | 26.594\*\*\*/ 2.971\* | 0.001/ 0.084 |

Note: **†** H0: linear cointegration | H1: threshold cointegration. Trimming parameter is 0.05, number of bootstrapping is set to 1000, type of bootstrapping is ‘fixed Regression’. *a* two-regime TVECM with one threshold, *b* three-regime TVECM with two thresholds. *c* the first number in the column refers to the hypothesis H0: no cointegration | H1: at least one cointegration equation. The second number in the columns refers to the hypothesis H0: one cointegration equation | H1: two cointegration equations. \* p<0.10, \*\* p<0.05, \*\*\* p<0.01.

**Table S4.** Tests of cointegration: intraregional analysis

|  |  |  |  |
| --- | --- | --- | --- |
| price pair | Hansen & Seo test (2002)**†,** *a*  | Larsen test (2012)**†,** *b*  | Johansen test (1988) *c* |
| sup-Waldtest statistic | 5% cr. value | p-value | trace test statistic  | p-value |
| *Black Earth* |
| Belgorod – Kursk | 14.270\*\* | 13.568 | 0.13 | 14.799\*\*/ 2.892 | 0.018/ 0.105 |
| Belgorod – Lipetsk | 13.630 | 16.228 | 0.16 | 29.167\*\*\*/ 4.277 | 0.002/ 0.372 |
| Belgorod – Tambov | 20.756\*\*\* | 13.707 | 0.01 | 26.637\*\*\*/ 2.057 | 0.001/0.178 |
| Belgorod – Voronezh | 13.468\* | 14.112 | 0.26 | 25.968\*\*\*/ 7.886\* | 0.007/0.086 |
| Kursk – Lipetsk | 12.413 | 19.277 | 0.41 | 21.096\*\*\*/ 12.320\* | 0.001/ 0.088 |
| Kursk – Tambov | 18.881\*\* | 17.054 | 0.01 | 43.219\*\*\*/ 7.574\* | 0.000/ 0.099 |
| Kursk – Voronezh | 24.478\* | 25.016 | 0.38 | 44.483/\*\*\* 7.635\* | 0.000/ 0.096 |
| Lipetsk – Tambov | 11.915 | 14.056 | 0.29 | 13.617\*\*/ 2.343 | 0.030/ 0.148 |
| Lipetsk – Voronezh | 18.238\*\* | 18.120 | 0.41 | 10.719\*/ 0.551 | 0.091/0.520 |
| Tambov – Voronezh | 20.310\*\*\* | 14.203 | 0.01 | 26.475\*\*\*/ 2.617 | 0.001/ 0.124 |
| *West Siberia* |
| Kemerovo – Altai | 12.935\*\* | 12.939 | 0.18 | 18.767\* / 5.482  | 0.079 / 0.135 |
| Kemerovo – Novosibirsk | 19.089\*\*\* | 13.139 | 0.03 | 30.322\*\*\* / 6.506 | 0.002 / 0.155 |
| Kemerovo – Omsk | 9.957 | 12.789 | 0.56 | 21.270\*\* / 4.098 | 0.036 / 0.398 |
| Kemerovo – Tomsk | 9.368 | 13.356 | 0.09 | 22.650\*\* / 4.798 | 0.023 / 0.306 |
| Novosibirsk – Altai | 15.724\*\* | 13.972 | 0.32 | 26.038\*\*\* / 5.217 | 0.007 / 0.261 |
| Novosibirsk – Omsk | 23.676\*\*\* | 17.139 | 0.01 | 38.701\*\*\* / 3.545 | 0.001 / 0.484 |
| Tomsk – Novosibirsk | 16.473\* | 17.202 | 0.35 | 53.816\*\*\* / 3.928 | 0.001 / 0.423 |
| Tomsk – Altai | 21.845\*\* | 21.089 | 0.32 | 25.430\*\*\* / 6.325 | 0.009 / 0.167 |
| Tomsk – Omsk | 15.671\*\* | 13.328 | 0.15 | 21.658\*\* / 3.772 | 0.032 / 0.447 |
| Altai – Omsk | 13.971\*\* | 13.345 | 0.04 | 23.557\*\* / 5.001 | 0.017 / 0.283 |
| Tyumen – Altai | 10.489 | 12.914 | 0.09 | 25.297\*\*\* / 5.671 | 0.009 / 0.218 |
| Tyumen – Kemerovo | 14.738\* | 15.638 | 0.02 | 18.526\* / 6.927 | 0.085 / 0.130 |
| Tyumen – Novosibirsk | 17.544\*\*\* | 13.067 | 0.16 | 28.365\*\*\* / 2.805 | 0.003 / 0.618 |
| Tyumen – Omsk | 15.521\*\*\* | 13.185 | 0.06 | 33.161\*\*\* / 3.703 | 0.001 / 0.458 |
| Tyumen – Tomsk | 13.238\* | 13.432 | 0.13 | 33.269\*\*\* / 4.064 | 0.001 / 0.403 |
| (*continued*) |
| **Table S4.** (*continued*) |
| price pair | Hansen & Seo test (2002)**†,** *a*  | Larsen test (2012)**†,** *b*  | Johansen test (1988) *c* |
| sup-Waldtest statistic | 5% cr. value | p-value | trace test statistic  | p-value |
| *Iowa* |
| Cedar Rapids – Emmetsburg | 15.803\*\* | 15.107 | 0.02 | 16.035/ 20.261 | 0.172/ 0.177 |
| Clinton – Cedar Rapids | 16.616\*\* | 15.122 | 0.03 | 24.361\*\*/ 4.720 | 0.012/ 0.315 |
| Clinton – Davenport | 12.583 | 15.138 | 0.11 | 28.464\*\*/ 6.592 | 0.023/ 0.388 |
| Clinton – Emmetsburg | 18.130\*\*\* | 14.897 | 0.01 | 21.362\*\*/ 5.334 | 0.035/ 0.248 |
| Eddyville – Cedar Rapids | 19.128\*\*\* | 15.515 | 0.02 | 19.644\*/ 4.475 | 0.060/ 0.345 |
| Clinton – Muscatine | 11.728 | 15.158 | 0.38 | 36.069\*\*\*/ 3.637 | 0.001/ 0.468 |
| Davenport – Cedar Rapids | 11.988 | 14.900 | 0.09 | 10.243/ 2.104 | 0.615/ 0.756 |
| Davenport – Emmetsburg | 14.038\* | 15.428 | 0.28 | 28.627\*\*/ 9.429 | 0.022/ 0.155 |
| Eddyville – Clinton | 13.870\* | 15.136 | 0.08 | 24.082\*\*/ 5.418 | 0.014/ 0.240 |
| Eddyville – Davenport | 14.210\* | 14.514 | 0.33 | 14.996/ 5.115 | 0.226/ 0.271 |
| Eddyville – Emmetsburg | 14.515 | 17.805 | 0.06 | 18.428\*/ 2.966 | 0.0876/ 0.587 |
| Eddyville – Keokuk | 31.678\* | 32.574 | 0.13 | 14.545\*\*/ 0.425 | 0.020/ 0.577 |
| Eddyville – Muscatine | 13.144 | 15.105 | 0.09 | 20.042\*/ 5.567 | 0.053/ 0.226 |
| Keokuk – Cedar Rapids | 13.884 | 15.448 | 0.32 | 13.176/ 4.144 | 0.349/ 0.391 |
| Keokuk – Clinton | 15.017\*\* | 14.855 | 0.09 | 12.640/ 4.020 | 0.393/ 0.409 |
| Keokuk – Davenport | 15.058 | 18.674 | 0.35 | 24.048\*\*/ 7.208 | 0.014/ 0.115 |
| Keokuk – Emmetsburg | 10.561 | 15.130 | 0.09 | 15.995/ 5.114 | 0.174/ 0.271 |
| Keokuk – Muscatine | 17.933\* | 18.504 | 0.27 | 23.704\*\*/ 7.129 | 0.016/ 0.119 |
| Muscatine – Cedar Rapids | 16.707\*\* | 14.648 | 0.01 | 19.604\*/ 9.164 | 0.061/ 0.340 |
| Muscatine – Davenport | 14.732\* | 14.835 | 0.70 | 7.034/ 0.705 | 0.321/ 0.460 |
| Muscatine – Emmetsburg | 10.496 | 14.547 | 0.23 | 18.233\*/ 7.287 | 0.092/ 0.112 |
| W. Burlington – Cedar Rapids | 18.285\* | 18.799 | 0.54 | 10.347/ 1.997 | 0.605/ 0.778 |
| W. Burlington – Clinton | 12.711 | 14.691 | 0.12 | 12.578/ 3.912 | 0.398/ 0.425 |
| W. Burlington – Davenport | 14.944 | 18.461 | 0.11 | 26.991\*\*\*/ 6.291 | 0.005/ 0.169 |
| W. Burlington – Eddyville | 15.427\*\* | 14.625 | 0.01 | 20.565\*\*/ 6.149 | 0.045/ 0.179 |
| W. Burlington – Emmetsburg | 21.514\*\*\* | 14.811 | 0.01 | 26.240\*\*/ 6.535 | 0.045/ 0.395 |
| W. Burlington – Keokuk | 16.866 | 18.003 | 0.01 | 19.107\*/ 6.093 | 0.071/ 0.183 |
| W. Burlington Muscatine | 20.126\*\* | 19.244 | 0.23 | 21.819\*\*/ 6.776 | 0.030/ 0.138 |
| *North Carolina* |
| Candor – Creswell | 18.470\*\*\* | 14.107 | 0.03 | 19.048\*/ 3.416 | 0.072/ 0.505 |
| Cofield – Candor | 19.469\*\* | 17.478 | 0.07 | 10.149/ 3.674 | 0.625/ 0.462 |
| Cofield – Creswell | 12.048 | 14.379 | 0.18 | 21.288\*\*/ 4.576 | 0.036/ 0.333 |
| Laurinburg – Candor | 15.472\*\* | 14.902 | 0.14 | 16.517/ 3.727 | 0.151/ 0.454 |
| Laurinburg – Cofield | 11.681 | 17.164 | 0.25 | 8.813/ 3.467 | 0.753/ 0.497 |
| Laurinburg – Creswell | 15.206\*\* | 14.573 | 0.10 | 22.975\*\*/ 4.832 | 0.020/ 0.302 |
| Laurinburg – Roaring River | 18.305\*\*\* | 14.860 | 0.03 | 15.741/ 2.987 | 0.186/ 0.582 |
| Laurinburg – Statesville | 20.286 | 14.865 | 0.01 | 14.781/ 3.979 | 0.239/ 0.415 |
| Roaring River – Candor | 12.362 | 15.349 | 0.06 | 24.230\*\*/ 2.991 | 0.013/ 0.582 |
| Roaring River – Cofield | 13.446\* | 13.669 | 0.16 | 13.100/ 3.062 | 0.355/ 0.569 |
| Roaring River – Creswell | 10.038 | 14.862 | 0.34 | 26.770\*\*\*/ 3.523 | 0.005/ 0.487 |
| Roaring River – Statesville | 16.402 | 17.659 | 0.09 | 14.970/2.862 | 0.228/ 0.606 |
| Statesville – Candor | 13.726\* | 14.354 | 0.19 | 12.392/ 3.310 | 0.414/ 0.524 |
| Statesville – Cofield | 15.691 | 17.822 | 0.07 | 11.612/ 3.862 | 0.484/ 0.433 |
| Statesville – Creswell | 12.661 | 14.357 | 0.18 | 18.602\*/ 3.773 | 0.083/ 0.446 |

Note: **†** H0: linear cointegration | H1: threshold cointegration. Trimming parameter is 0.05, number of bootstrapping is set to 1000, type of bootstrapping is ‘fixed Regression’. *a* two-regime TVECM with one threshold, *b* three-regime TVECM with two thresholds. *c* the first number in the column refers to the hypothesis H0: no cointegration | H1: at least one cointegration equation. The second number in the columns refers to the hypothesis H0: one cointegration equation | H1: two cointegration equations. \* p<0.10, \*\* p<0.05, \*\*\* p<0.01.

**Table S5.** Parameters of long-run price equilibrium regression: USA, interregional analysis

|  |  |  |  |
| --- | --- | --- | --- |
| price pair | distance(km) | long-run pricetransmission elasticities ($β$) | interceptparameter ($α$) |
| Arkansas – Illinois  | 595 | - | - |
| Arkansas – Iowa | 475 | 1.020 | -0.054 |
| Arkansas – Kansas | 993 | - | - |
| Arkansas – Minnesota | 531 | - | - |
| Arkansas – Missouri | 393 | 0.888 | 0.593 |
| Arkansas – Nebraska | 581 | 0.912 | 0.468 |
| Arkansas – S. Dakota | 1144 | 0.895 | 0.635 |
| California – Illinois | 3288 | 0.948 | 1.151 |
| California – Iowa | 3084 | 0.957 | -0.685 |
| California – Kansas | 2356 | 1.201 | -2.134 |
| California – Minnesota | 3224 | 0.715 | 2.336 |
| California – Missouri | 2945 | 0.724 | 2.282 |
| California – Nebraska | 2675 | 0.767 | 2.064 |
| California – S. Dakota | 2548 | 0.760 | 2.170 |
| Colorado – Illinois | 1720 | 0.644 | 1.786 |
| Colorado – Iowa | 1273 | 0.752 | 1.230 |
| Colorado – Kansas | 494 | - | - |
| Colorado – Minnesota | 1482 | - | - |
| Colorado – Missouri | 974 | 0.856 | 0.715 |
| Colorado – Nebraska | 866 | - | - |
| Colorado – S. Dakota | 901 | 0.826 | 0.781 |
| Oklahoma – Illinois | 1315 | 0.613 | 1.935 |
| Oklahoma – Iowa | 1289 | 0.705 | 1.456 |
| Oklahoma – Kansas | 220 | 0.890 | 0.528 |
| Oklahoma – Minnesota | 1498 | 0.867 | 0.648 |
| Oklahoma – Missouri | 789 | 0.810 | 0.939 |
| Oklahoma – Nebraska | 874 | - | - |
| Oklahoma – S. Dakota | 1073 | 0.752 | 1.140 |
| Oregon – Illinois | 3642 | 0.843 | 0.593 |
| Oregon – Iowa | 2836 | 0.900 | 0.720 |
| Oregon – Kansas | 2472 | 0.755 | 1.454 |
| Oregon – Minnesota | 2926 | 0.765 | 1.401 |
| Oregon – Missouri | 2895 | 0.773 | 1.350 |
| Oregon – Nebraska | 2660 | 0.820 | 1.110 |
| Oregon – S. Dakota | 2245 | 0.806 | 1.253 |
| Texas – Illinois | 1226 | 0.674 | 1.575 |
| Texas – Iowa | 1487 | 0.787 | 0.985 |
| Texas – Kansas | 380 | 0.990 | -0.050 |
| Texas – Minnesota | 1695 | 0.986 | -0.022 |
| Texas – Missouri | 985 | 0.913 | 0.356 |
| Texas – Nebraska | 1032 | 0.903 | 0.414 |
| Texas – S. Dakota | 1262 | 0.848 | 0.595 |
| Virginia – Illinois | 1349 | 1.299 | -1.412 |
| Virginia – Iowa | 1897 | 1.097 | -0.387 |
| Virginia – Kansas | 2356 | 0.911 | 0.549 |
| (*continued*) |
| **Table S5.** (*continued*) |
| price pair | distance(km) | long-run pricetransmission elasticities ($β$) | interceptparameter ($α$) |
| Virginia – Minnesota | 1833 | 0.869 | 0.745 |
| Virginia – Missouri | 1754 | 0.946 | 0.358 |
| Virginia – Nebraska | 2037 | 0.895 | 0.598 |
| Virginia – S. Dakota | 2565 | 0.902 | 0.646 |
| Washington – Illinois | 3375 | 0.687 | 0.784 |
| Washington – Iowa | 2393 | 0.799 | 0.080 |
| Washington – Kansas | 2351 | 0.956 | 1.366 |
| Washington – Minnesota | 2482 | 0.956 | 1.359 |
| Washington – Missouri | 2628 | 0.985 | 1.202 |
| Washington – Nebraska | 2342 | - | - |
| Washington – S. Dakota | 1801 | 1.008 | 1.173 |
| Wyoming – Illinois | 1782 | 0.585 | 2.208 |
| Wyoming – Iowa | 1221 | 0.690 | 1.692 |
| Wyoming – Kansas | 721 | 0.879 | 0.789 |
| Wyoming – Minnesota | 1310 | - | - |
| Wyoming – Missouri | 1033 | 0.788 | 1.232 |
| Wyoming – Nebraska | 800 | - | - |
| Wyoming – S. Dakota | 653 | 0.780 | 1.189 |

Note: The hyphen (-) = not applicable, because the existence of long-run equilibrium is not confirmed.

**Table S6.** Parameters of long-run price equilibrium regression: intraregional analysis

|  |  |  |  |
| --- | --- | --- | --- |
| price pair | distance (km) | long-run pricetransmission elasticities ($β$) | interceptparameter ($α$) |
| *Black Earth* |
| Belgorod – Kursk | 142 | 0.932 | 0.666 |
| Belgorod – Lipetsk | 317 | 0.890 | 1.045 |
| Belgorod – Tambov | 477 | 0.944 | 0.442 |
| Belgorod – Voronezh | 255 | 0.919 | 0.773 |
| Kursk – Lipetsk | 323 | 0.861 | 1.262 |
| Kursk – Tambov | 451 | 0.949 | 0.478 |
| Kursk – Voronezh | 228 | 0.902 | 0.885 |
| Lipetsk – Tambov | 134 | 0.938 | 0.534 |
| Lipetsk – Voronezh | 133 | 0.987 | 0.120 |
| Tambov – Voronezh | 220 | 1.010 | -0.071 |
| *West Siberia* |
| Kemerovo – Altai  | 411 | 0.856 | 1.300 |
| Kemerovo – Novosibirsk | 267 | 0.672 | 3.043 |
| Kemerovo – Omsk | 906 | 0.652 | 3.234 |
| Kemerovo – Tomsk | 218 | 0.808 | 1.710 |
| Novosibirsk – Altai | 226 | 0.906 | 0.786 |
| Novosibirsk – Omsk | 654 | 0.797 | 1.852 |
| Tomsk – Novosibirsk | 268 | 0.776 | 2.160 |
| Tomsk – Altai | 490 | 0.913 | 0.759 |
| Tomsk – Omsk | 911 | 0.799 | 1.951 |
| Altai – Omsk | 880 | 0.728 | 2.560 |
| (*continued*) |
| **Table S6.** (*continued*) |
| price pair | distance (km) | long-run pricetransmission elasticities ($β$) | interceptparameter ($α$) |
| Tyumen – Altai | 1504 | 0.855 | 1.259 |
| Tyumen – Kemerovo | 1548 | 0.788 | 1.981 |
| Tyumen – Novosibirsk | 1280 | 0.838 | 1.485 |
| Tyumen – Omsk | 624 | 0.757 | 2.223 |
| Tyumen – Tomsk | 1538 | 0.826 | 1.492 |
| *Iowa* |
| Cedar Rapids – Emmetsburg | 354 | 0.780 | 1.143 |
| Clinton – Cedar Rapids | 138 | 0.979 | 0.110 |
| Clinton – Davenport | 66 | 0.733 | 1.367 |
| Clinton – Emmetsburg | 489 | 1.084 | -0.494 |
| Clinton – Muscatine | 114 | 0.950 | 0.264 |
| Davenport – Cedar Rapids | 129 | 1.048 | -0.278 |
| Davenport – Emmetsburg | 483 | 0.823 | 0.891 |
| Eddyville – Cedar Rapids | 174 | 1.066 | -0.374 |
| Eddyville – Clinton | 290 | 1.083 | -0.468 |
| Eddyville – Davenport | 240 | 0.928 | 0.359 |
| Eddyville – Emmetsburg | 367 | 0.856 | 0.726 |
| Eddyville – Keokuk | 182 | 0.891 | 0.523 |
| Eddyville – Muscatine | 166 | 1.088 | -0.474 |
| Keokuk – Cedar Rapids | 188 | - | - |
| Keokuk – Clinton | 253 | 1.083 | -0.451 |
| Keokuk – Davenport | 190 | 0.896 | 0.527 |
| Keokuk – Emmetsburg | 542 | 0.779 | 1.125 |
| Keokuk – Muscatine | 140 | 1.082 | -0.428 |
| Muscatine – Cedar Rapids | 105 | 0.973 | 0.122 |
| Muscatine – Davenport | 47 | 0.766 | 1.184 |
| Muscatine – Emmetsburg | 462 | 1.065 | -0.379 |
| W. Burlington – Cedar Rapids | 159 | 1.043 | -0.239 |
| W. Burlington – Clinton | 193 | - | - |
| W. Burlington – Davenport | 126 | 1.020 | -0.113 |
| W. Burlington – Eddyville | 151 | 0.970 | 0.129 |
| W. Burlington – Emmetsburg | 512 | 0.890 | 0.506 |
| W. Burlington – Keokuk | 66 | 0.921 | 0.389 |
| W. Burlington – Muscatine | 76 | 1.085 | -0.440 |
| *North Carolina* |
| Candor – Creswell | 360 | 0.747 | 1.402 |
| Cofield – Candor | 333 | 1.043 | -0.286 |
| Cofield – Creswell | 97 | 0.883 | 0.656 |
| Laurinburg – Candor | 71 | 1.010 | -0.071 |
| Laurinburg – Cofield | 343 | - | - |
| Laurinburg – Creswell | 370 | 1.048 | -0.367 |
| Laurinburg – Roaring River | 261 | 0.966 | 0.152 |
| Laurinburg – Statesville | 211 | 0.921 | 0.356 |
| Roaring River – Candor | 192 | 0.988 | 0.065 |
| Roaring River – Cofield | 286 | 0.693 | 1.630 |
| Roaring River – Creswell | 475 | 0.752 | 1.382 |
| Roaring River – Statesville | 65 | 0.933 | 0.404 |
| Statesville – Candor | 157 | 0.934 | 0.392 |
| Statesville – Cofield | 439 | 1.059 | -0.304 |
| Statesville – Creswell | 470 | 1.108 | -0.627 |

Note: The hyphen (-) = not applicable, because the existence of long-run equilibrium is not confirmed.

**Table S7.** Results of TVECM and VECM: interregional analysis†

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| price pair | lower regime |  | middle regime / VECM parameters *a* |  | upper regime | total adjustment*b* |  |
| sp. adj. ($ρ\_{1}$) | p-value | threshold($τ\_{1}$) | sp. adj. ($ρ\_{2}$) | p-value | threshold ($τ\_{2}$) | sp. adj. ($ρ\_{3}$) | p-value | lower | middle | upper | band ofinaction *c* |
| *Russia* |
| Central – Black Earth | -0.379 | 0.360 | *-0.021* | -0.373 | 0.336 | *0.018* | -0.581\* | 0.089 | 0.564 | 0.596 | 0.929 | *0.039* |
| Black Earth – Central | 0.564\* | 0.072 |  | 0.596\*\* | 0.035 |  | 0.616\*\* | 0.015 |  |  |  |  |
| Central – Volga | - | - | - | -0.438\*\*\* | 0.001 | - | - | - | - | 0.641 | - | - |
| Volga – Central | - | - |  | 0.279\*\* | 0.047 |  | - | - |  |  |  |  |
| Central –Urals | -0.057 | 0.757 | *-0.047* | -0.276 | 0.259 | *0.029* | -0.316\*\* | 0.030 | 0.524 | - | 0.316 | *0.076* |
| Urals – Central | 0.524\*\*\* | 0.004 |  | 0.326 | 0.214 |  | 0.190 | 0.233 |  |  |  |  |
| Central – W. Siberia | -0.076 | 0.646 | *-0.062* | -0.194 | 0.311 | *0.021* | -0.304\*\* | 0.014 | 0.452 | - | 0.304 | *0.083* |
| W. Siberia – Central | 0.454\*\* | 0.041 |  | 0.157 | 0.574 |  | -0.010 | 0.955 |  |  |  |  |
| N. Caucasus – Black Earth | -0.371\*\* | 0.041 | *-0.021* | -0.371\*\* | 0.041 | *0.020* | -0.371\*\* | 0.041 | 0.371 | 0.371 | 0.371 | *0.041* |
| Black Earth – N. Caucasus | -0.036 | 0.809 |  | -0.036 | 0.809 |  | -0.036 | 0.809 |  |  |  |  |
| N. Caucasus – Central | -0.510\*\*\* | 0.025 | *-0.030* | -0.386\* | 0.088 | *0.020* | -0.308 | 0.136 | 0.510 | 0.385 | - | *0.050* |
| Central – N. Caucasus | -0.281 | 0.187 |  | 0.215 | 0.299 |  | -0.061 | 0.744 |  |  |  |  |
| N. Caucasus – Volga | -0.306\* | 0.078 | *-0.038* | -0.323 | 0.136 | *0.012* | -0.283\* | 0.060 | 0.306 | - | 0.283 | *0.050* |
| Volga – N. Caucasus | -0.203 | 0.276 |  | -0.143 | 0.569 |  | -0.174 | 0.328 |  |  |  |  |
| N. Caucasus – Urals | - | - | - | 0.045 | 0.774 | - | - | - | - | 0.464 | - | - |
| Urals – N. Caucasus | - | - |  | 0.464\*\*\* | 0.000 |  | - | - |  |  |  |  |
| N. Caucasus – W. Siberia | -0.219 | 0.146 | *-0.049* | -0.234\*\* | 0.036 | *0.029* | -0.234\*\* | 0.036 | - | 0.234 | 0.234 | *0.078* |
| W. Siberia – N. Caucasus | -0.020 | 0.926 |  | 0.111 | 0.573 |  | 0.111 | 0.573 |  |  |  |  |
| Black Earth – Volga | -0.179\* | 0.086 | *-0.046* | -0.271\* | 0.052 | *0.011* | -0.179\* | 0.086 | 0.179 | 0.271 | 0.179 | *0.057* |
| Volga – Black Earth | 0.044 | 0.781 |  | -0.006 | 0.979 |  | 0.044 | 0.781 |  |  |  |  |
| Black Earth – Urals | 0.122 | 0.318 | *-0.059* | 0.122 | 0.318 | *0.031* | 0.010 | 0.928 | 0.503 | 0.503 | 0.349 | *0.090* |
| Urals – Black Earth | 0.503\*\*\* | 0.000 |  | 0.503\*\*\* | 0.000 |  | 0.349\*\* | 0.016 |  |  |  |  |
| Black Earth – W. Siberia | - | - | - | 0.051 | 0.659 | - | - | - | - | 0.598 | - | - |
| W. Siberia – Black Earth | - | - |  | 0.598\*\*\* | 0.000 |  | - | - |  |  |  |  |
| Volga – Urals | -0.294 | 0.203 | *-0.058* | -0.038 | 0.858 | *0.038* | -0.506\*\* | 0.014 | 0.376 | 0.360 | 0.506 | *0.096* |
| Urals – Volga | 0.376\* | 0.067 |  | 0.360\*\* | 0.043 |  | 0.226 | 0.245 |  |  |  |  |
| (*continued*) |
| **Table S7.** (*continued*) |
| price pair | lower regime |  | middle regime / VECM parameters *a* |  | upper regime | total adjustment*b* |  |
| sp. adj. ($ρ\_{1}$) | p-value | threshold($τ\_{1}$) | sp. adj. ($ρ\_{2}$) | p-value | threshold ($τ\_{2}$) | sp. adj. ($ρ\_{3}$) | p-value | lower | middle | upper | band ofinaction *c* |
| Volga – W. Siberia | -0.262 | 0.274 | *-0.056* | -0.362\*\* | 0.035 | *0.035* | -0.493\*\*\* | 0.004 | - | 0.362 | 0.493 | *0.091* |
| W. Siberia – Volga | 0.385 | 0.125 |  | 0.186 | 0.228 |  | -0.051 | 0.763 |  |  |  |  |
| Urals – W. Siberia | -0.370\* | 0.072 | *-0.027* | -0.337 | 0.183 | *0.012* | -0.370 | 0.141 | 0.370 | - | - | *0.039* |
| W. Siberia – Urals | 0.381 | 0.157 |  | 0.306 | 0.324 |  | 0.022 | 0.951 |  |  |  |  |
| *USA* |
| Arkansas – Iowa | -0.303 | 0.468 | *-0.090* | -0.481 | 0.249 | *0.008* | -0.389 | 0.378 | - | - | - | *0.098* |
| Iowa – Arkansas | 0.421 | 0.334 |  | -0.010 | 0.984 |  | -0.006 | 0.991 |   |   |   |  |
| Arkansas – Missouri | -0.767\* | 0.059 | *-0.025* | -0.767\* | 0.059 | *0.024* | -0.312 | 0.488 | 0.767 | 0.767 | - | *0.049* |
| Missouri – Arkansas  | -0.076 | 0.898 |  | -0.076 | 0.898 |  | 0.671 | 0.120 |   |   |   |  |
| Arkansas – Nebraska | -0.835\*\* | 0.020 | *-0.034* | -0.726\* | 0.059 | *0.012* | -0.835\*\* | 0.020 | 0.835 | 0.726 | 0.835 | *0.047* |
| Nebraska – Arkansas | -0.351 | 0.520 |  | -0.118 | 0.817 |  | -0.351 | 0.520 |   |   |   |  |
| Arkansas – S. Dakota | - | - | *-* | -0.020 | 0.951 | *-* | - | - | - | 0.581 | - | *-* |
| S. Dakota – Arkansas  | - | - |  | 0.581\* | 0.082 |  | - | - |   |   |   |  |
| California – Illinois | 0.012 | 0.974 | *-0.044* | 0.065 | 0.859 | *0.016* | -0.010 | 0.978 | 0.640 | 0.680 | 0.613 | *0.060* |
| Illinois – California | 0.640\* | 0.059 |  | 0.680\*\* | 0.037 |  | 0.613\* | 0.071 |   |   |   |  |
| California – Iowa | 0.105 | 0.816 | *-0.032* | -0.118 | 0.831 | *0.010* | -0.576 | 0.175 | 0.813 | - | - | *0.042* |
| Iowa – California | 0.813\*\* | 0.051 |  | 0.510 | 0.383 |  | -0.021 | 0.975 |   |   |   |  |
| California – Kansas | - | - | *-* | -0.250 | 0.424 | *-* | - | - | - | 0.681 | - | *-* |
| Kansas – California | - | - |  | 0.681\* | 0.057 |  | - | - |   |   |   |  |
| California – Minnesota | -0.783\* | 0.061 | *-0.022* | -0.818\* | 0.081 | *0.012* | -0.815\*\* | 0.050 | 0.783 | 0.818 | - | *0.034* |
| Minnesota – California | -0.307 | 0.700 |  | -0.237 | 0.780 |  | -0.531 | 0.526 |   |   |   |  |
| California – Missouri | -0.131 | 0.730 | *-0.037* | -0.131 | 0.730 | *0.035* | -0.291 | 0.580 | 0.959 | 0.959 | 0.808 | *0.073* |
| Missouri – California | 0.959\*\*\* | 0.002 |  | 0.959\*\*\* | 0.002 |  | 0.808\* | 0.097 |   |   |   |  |
| California – Nebraska | -0.527 | 0.327 | *-0.028* | -0.791\*\* | 0.047 | *0.020* | -0.795\* | 0.080 | - | 0.791 | 0.795 | *0.047* |
| Nebraska – California | 0.537 | 0.401 |  | 0.406 | 0.507 |  | 0.304 | 0.659 |   |   |   |  |
| California – S. Dakota | -0.298 | 0.471 | *-0.035* | -0.343 | 0.431 | *0.005* | -0.298 | 0.471 | - | - | - | *0.041* |
| S. Dakota – California | 0.719 | 0.152 |  | 0.741 | 0.146 |  | 0.719 | 0.152 |   |   |   |  |
| (*continued*) |
| **Table S7.** (*continued*) |
| price pair | lower regime |  | middle regime / VECM parameters *a* |  | upper regime | total adjustment*b* |  |
| sp. adj. ($ρ\_{1}$) | p-value | threshold($τ\_{1}$) | sp. adj. ($ρ\_{2}$) | p-value | threshold ($τ\_{2}$) | sp. adj. ($ρ\_{3}$) | p-value | lower | middle | upper | band ofinaction *c* |
| Colorado – Illinois | 1.036\*\* | 0.048 | *-0.028* | 1.036\*\* | 0.048 | *0.025* | 1.036\*\* | 0.048 | 0.736 | 0.736 | 0.736 | *0.053* |
| Illinois – Colorado | 0.736\*\* | 0.015 |  | 0.736\*\* | 0.015 |  | 0.736\*\* | 0.015 |   |   |   |  |
| Colorado – Iowa | - | - | *-* | 1.421\*\*\* | 0.007 | *-* | - | - | - | 0.991 | - | *-* |
| Iowa – Colorado | - | - |  | 0.991\*\*\* | 0.001 |  | - | - |   |   |   |  |
| Colorado – Missouri | 0.254 | 0.589 | *-0.042* | 0.223 | 0.587 | *0.032* | 0.254 | 0.589 | 0.632 | 0.556 | 0.632 | *0.074* |
| Missouri – Colorado | 0.632\* | 0.075 |  | 0.556\* | 0.088 |  | 0.632\* | 0.075 |   |   |   |  |
| Colorado – S. Dakota | -0.003 | 0.995 | *-0.019* | -0.099 | 0.856 | *0.025* | -0.003 | 0.995 | - | - | - | *0.044* |
| S. Dakota – Colorado | 0.586 | 0.177 |  | 0.531 | 0.298 |  | 0.586 | 0.177 |   |   |   |  |
| Oklahoma – Illinois | 1.347\*\* | 0.047 | *-0.024* | 1.347\*\* | 0.047 | *0.024* | 1.347\*\* | 0.047 | 0.875 | 0.875 | 0.875 | *0.048* |
| Illinois – Oklahoma | 0.875\*\*\* | 0.003 |  | 0.875\*\*\* | 0.003 |  | 0.875\*\*\* | 0.003 |   |   |   |  |
| Oklahoma – Iowa | 0.099 | 0.859 | *-0.091* | 0.099 | 0.859 | *0.023* | 0.099 | 0.859 | 0.895 | 0.895 | 0.895 | *0.114* |
| Iowa – Oklahoma | 0.895\*\*\* | 0.008 |  | 0.895\*\*\* | 0.008 |  | 0.895\*\*\* | 0.008 |   |   |   |  |
| Oklahoma – Kansas | -0.225 | 0.787 | *-0.012* | -0.225 | 0.787 | *0.023* | -0.225 | 0.787 | - | - | - | *0.035* |
| Kansas – Oklahoma | 0.446 | 0.513 |  | 0.446 | 0.513 |  | 0.446 | 0.513 |   |   |   |  |
| Oklahoma – Minnesota | -0.503 | 0.290 | *-0.040* | -0.503 | 0.290 | *0.014* | -0.239 | 0.641 | - | - | - | *0.054* |
| Minnesota – Oklahoma | -0.243 | 0.636 |  | -0.243 | 0.636 |  | 0.333 | 0.450 |   |   |   |  |
| Oklahoma – Missouri | 0.043 | 0.932 | *-0.053* | -0.006 | 0.990 | *0.028* | 0.043 | 0.932 | - | - | - | *0.081* |
| Missouri – Oklahoma | 0.561 | 0.117 |  | 0.480 | 0.174 |  | 0.561 | 0.117 |   |   |   |  |
| Oklahoma – S. Dakota | -0.138 | 0.709 | *-0.029* | -0.063 | 0.874 | *0.033* | -0.063 | 0.874 | - | - | - | *0.062* |
| S. Dakota – Oklahoma | 0.446 | 0.182 |  | 0.483 | 0.158 |  | 0.483 | 0.158 |   |   |   |  |
| Oregon – Illinois | 0.394 | 0.333 | *-0.020* | 0.622 | 0.217 | *0.014* | 1.408\*\* | 0.026 | 0.693 | 0.773 | 0.961 | *0.034* |
| Illinois – Oregon | 0.693\* | 0.059 |  | 0.773\*\* | 0.048 |  | 0.961\*\*\* | 0.008 |   |   |   |  |
| Oregon – Iowa | 0.901 | 0.165 | *-0.102* | 0.463 | 0.466 | *0.009* | 0.944 | 0.155 | 0.999 | - | 0.999 | *0.110* |
| Iowa – Oregon | 0.999\*\*\* | 0.005 |  | 0.807 | 0.123 |  | 0.999\*\*\* | 0.006 |   |   |   |  |
| Oregon – Kansas | 0.348 | 0.565 | *-0.016* | 0.579 | 0.402 | *0.010* | 0.593 | 0.392 | - | - | - | *0.026* |
| Kansas – Oregon | 0.691 | 0.250 |  | 0.785 | 0.190 |  | 0.791 | 0.186 |   |   |   |  |
| Oregon – Minnesota | -0.082 | 0.927 | *-0.004* | 0.015 | 0.987 | *0.008* | 0.255 | 0.797 | - | - | - | *0.012* |
| Minnesota – Oregon | 0.680 | 0.465 |  | 0.739 | 0.411 |  | 0.814 | 0.348 |   |   |   |  |
| (*continued*) |
| **Table S7.** (*continued*) |
| price pair | lower regime |  | middle regime / VECM parameters *a* |  | upper regime | total adjustment*b* |  |
| sp. adj. ($ρ\_{1}$) | p-value | threshold($τ\_{1}$) | sp. adj. ($ρ\_{2}$) | p-value | threshold ($τ\_{2}$) | sp. adj. ($ρ\_{3}$) | p-value | lower | middle | upper | band ofinaction *c* |
| Oregon – Missouri | - | - | *-* | 0.469 | 0.303 | *-* | - | - | - | 0.985 | - | *-* |
| Missouri – Oregon | - | - |  | 0.985\*\*\* | 0.001 |  | - | - |   |   |   |  |
| Oregon – Nebraska | - | - | *-* | 1.373\*\*\* | 0.008 | *-* | - | - | - | 0.970 | - | *-* |
| Nebraska – Oregon | - | - |  | 0.970\*\*\* | 0.001 |  | - | - |   |   |   |  |
| Oregon – S. Dakota | 0.031 | 0.945 | *-0.024* | 0.031 | 0.945 | *0.019* | 0.018 | 0.966 | - | - | - | *0.043* |
| S. Dakota – Oregon | 0.748 | 0.132 |  | 0.748 | 0.132 |  | 0.741 | 0.134 |   |   |   |  |
| Texas – Illinois | -0.999\*\*\* | 0.004 | *-0.009* | -0.999\*\*\* | 0.004 | *0.009* | -0.999\*\*\* | 0.004 | 0.999 | 0.999 | 0.999 | *0.018* |
| Illinois – Texas | -3.653\*\*\* | 0.000 |  | -3.629\*\*\* | 0.000 |  | -3.653\*\*\* | 0.000 |   |   |   |  |
| Texas – Iowa | 1.030 | 0.195 | *-0.100* | 1.030 | 0.195 | *0.014* | 1.030 | 0.195 | 0.996 | 0.996 | 0.996 | *0.113* |
| Iowa – Texas | 0.996\*\*\* | 0.007 |  | 0.996\*\*\* | 0.007 |  | 0.996\*\*\* | 0.007 |   |   |   |  |
| Texas – Kansas | 0.404 | 0.783 | *-0.014* | 0.404 | 0.783 | *0.008* | 0.438 | 0.767 | - | - | - | *0.021* |
| Kansas – Texas | 0.743 | 0.485 |  | 0.743 | 0.485 |  | 0.753 | 0.475 |   |   |   |  |
| Texas – Minnesota | - | - | *-* | -0.735 | 0.339 | *-* | - | - |   | - |   |  |
| Minnesota – Texas | - | - |  | -0.404 | 0.735 |  | - | - |   |   |   |  |
| Texas – Missouri | 0.316 | 0.567 | *-0.033* | -0.170 | 0.754 | *0.020* | 0.316 | 0.567 | 0.791  | - | 0.791  | *0.053* |
| Missouri – Texas | 0.791\*\* | 0.044 |  | 0.529 | 0.299 |  | 0.791\*\* | 0.044 |   |   |   |  |
| Texas – Nebraska | -0.428 | 0.328 | *-0.003* | -0.256 | 0.726 | *0.011* | -0.428 | 0.328 | - | - | - | *0.015* |
| Nebraska – Texas | -0.010 | 0.984 |  | 0.224 | 0.761 |  | -0.010 | 0.984 |   |   |   |  |
| Texas – S. Dakota | - | - | *-* | 0.213 | 0.550 | *-* | - | - | - | 0.766 | - | *-* |
| S. Dakota – Texas | - | - |  | 0.766\*\* | 0.011 |  | - | - |   |   |   |  |
| Virginia – Illinois | - | - | *-* | -0.050 | 0.910 | *-* | - | - | - | 0.617 | - | *-* |
| Illinois – Virginia | - | - |  | 0.617\* | 0.053 |  | - | - |   |   |   |  |
| Virginia – Iowa | - | - | *-* | -0.643\*\* | 0.023 | *-* | - | - | - | 0.643 | - | *-* |
| Iowa – Virginia | - | - |  | 0.384 | 0.247 |  | - | - |   |   |   |  |
| Virginia – Kansas | - | - | *-* | -0.924\*\*\* | 0.001 | *-* | - | - | - | 0.924 | - | *-* |
| Kansas – Virginia | - | - |  | -1.063\*\*\* | 0.009 |  | - | - |   |   |   |  |
| Virginia – Minnesota | - | - | *-* | -0.778\*\*\* | 0.001 | *-* | - | - | - | 0.778 | - | *-* |
| Minnesota – Virginia | - | - |  | -0.639\* | 0.078 |  | - | - |   |   |   |  |
| (*continued*) |
| **Table S7.** (*continued*) |
| price pair | lower regime |  | middle regime / VECM parameters *a* |  | upper regime | total adjustment*b* |  |
| sp. adj. ($ρ\_{1}$) | p-value | threshold($τ\_{1}$) | sp. adj. ($ρ\_{2}$) | p-value | threshold ($τ\_{2}$) | sp. adj. ($ρ\_{3}$) | p-value | lower | middle | upper | band ofinaction *c* |
| Virginia – Missouri | -0.886 | 0.017 | *-0.009* | -0.774\*\* | 0.036 | *0.023* | -0.774\*\* | 0.036 | 0.886 | 0.774 | 0.774 | *0.032* |
| Missouri – Virginia | -0.316 | 0.599 |  | -0.308 | 0.575 |  | -0.308 | 0.575 |   |   |   |  |
| Virginia – Nebraska | - | - | *-* | -0.600\*\*\* | 0.009 | *-* | - | - | - | 0.600 | - | *-* |
| Nebraska – Virginia | - | - |  | -0.308 | 0.281 |  | - | - |   |   |   |  |
| Virginia – S. Dakota | -0.509 | 0.052 | *-0.049* | -0.254 | 0.462 | *0.041* | -0.253 | 0.463 | 0.509 | - | - | *0.090* |
| S. Dakota – Virginia | -0.185 | 0.611 |  | 0.235 | 0.545 |  | 0.238 | 0.539 |   |   |   |  |
| Washington – Illinois | 0.668 | 0.190 | *-0.061* | 1.466\*\* | 0.026 | *0.020* | 1.466\*\*\* | 0.026 | 0.800 | 0.959 | 0.959 | *0.081* |
| Illinois – Washington | 0.800 | 0.013 |  | 0.959\*\*\* | 0.002 |  | 0.959\*\*\* | 0.002 |   |   |   |  |
| Washington – Iowa | -0.157 | 0.799 | *-0.011* | 0.589 | 0.500 | *0.015* | 0.589 | 0.500 | - | - | - | *0.026* |
| Iowa – Washington | 0.479 | 0.391 |  | 0.852 | 0.115 |  | 0.852 | 0.115 |   |   |   |  |
| Washington – Kansas | - | - | *-* | 1.200\* | 0.071 | *-* | - | - | - | 0.980 | - | *-* |
| Kansas – Washington | - | - |  | 0.980\*\*\* | 0.007 |  | - | - |   |   |   |  |
| Washington – Minnesota | -0.862 | 0.118 | *-0.024* | -0.862 | 0.118 | *0.005* | -0.521 | 0.466 | - | - | - | *0.029* |
| Minnesota – Washington | -0.621 | 0.553 |  | -0.621 | 0.553 |  | 0.105 | 0.911 |   |   |   |  |
| Washington – Missouri | 0.063 | 0.918 | *-0.035* | 0.081 | 0.896 | *0.020* | 0.095 | 0.879 | 0.900 | 0.903 | 0.905 | *0.055* |
| Missouri – Washington | 0.900 | 0.038 |  | 0.903\*\* | 0.037 |  | 0.905\*\* | 0.036 |   |   |   |  |
| Washington – S. Dakota | - | - | *-* | 0.546 | 0.135 | *-* | - | - | - | 0.929 | - | *-* |
| S. Dakota – Washington | - | - |  | 0.929\*\*\* | 0.001 |  | - | - |   |   |   |  |
| Wyoming – Illinois | - | - | *-* | 0.970\*\*\* | 0.001 | *-* | - | - | - | 0.581 | - | *-* |
| Illinois – Wyoming | - | - |  | 0.581\*\*\* | 0.001 |  | - | - |   |   |   |  |
| Wyoming – Iowa | - | - | *-* | 1.036\*\*\* | 0.008 | *-* | - | - | - | 0.851 | - | *-* |
| Iowa – Wyoming | - | - |  | 0.851\*\*\* | 0.001 |  | - | - |   |   |   |  |
| Wyoming – Kansas | - | - | *-* | 1.595\*\* | 0.021 | *-* | - | - | - | 0.927 | - | *-* |
| Kansas – Wyoming | - | - |  | 0.927\*\*\* | 0.001 |  | - | - |   |   |   |  |
| Wyoming – Missouri | 0.276 | 0.622 | *-0.060* | -0.431 | 0.135 | *0.045* | 1.029\* | 0.070 | 0.681 | - | 0.681 | *0.105* |
| Missouri – Wyoming | 0.681 | 0.097 |  | 0.064 | 0.841 |  | 0.874\*\*\* | 0.005 |   |   |   |  |
| Wyoming – S. Dakota | - | - | *-* | 0.819\*\* | 0.031 | *-* | - | - | - | 0.959 | - | *-* |
| S. Dakota – Wyoming | - | - |  | 0.959\*\*\* | 0.001 |  | - | - |   |   |   |  |

Note: †to make speed of adjustment parameters of different frequencies comparable we convert them from weekly to biweekly frequency by using following formula $|ρ|^{biweekly}=1-(1-|ρ|^{weekly})^{2}$ for Russia and the USA. *a*parametersfrom the linear VECM are not regime-specific and thresholds are not estimated. Thus, linear VECM estimates are presented in the middle regime column. *b*total adjustment in one regime is calculated as the sum of the absolute value of the respective regime-specific speed of adjustment parameters of the TVECM significant at least 10% level. *c* the band of inaction is given as the difference between the absolute value of the upper and lower threshold. The hyphen (-) = not applicable. \* p<0.10, \*\* p<0.05, \*\*\* p<0.01.

**Table S8.** Results of TVECM and VECM: intraregional analysis †

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| price pair | lower regime |  | middle regime / VECM parameters *a* |  | upper regime | total adjustment*b* |  |
| sp. adj. ($ρ\_{1}$) | p-value | threshold($τ\_{1}$) | sp. adj. ($ρ\_{2}$) | p-value | threshold ($τ\_{2}$) | sp. adj. ($ρ\_{3}$) | p-value | lower | middle | upper | band ofinaction *c* |
| *Black Earth* |
| Belgorod – Kursk | -0.350\*\*\* | 0.004 | *-0.048* | -0.349\*\*\* | 0.004 | *0.032* | -0.350\*\*\* | 0.004 | 0.350 | 0.349 | 0.350 | *0.080* |
| Kursk – Belgorod  | 0.109 | 0.479 |  | 0.105 | 0.501 |  | 0.025 | 0.479 |  |  |  |  |
| Belgorod – Lipetsk | - | - | *-* | -0.357\*\*\* | 0.001 | *-* | - | - | - | 0.357 | - | *-* |
| Lipetsk – Belgorod  | - | - |  | -0.209\*\* | 0.034 |  | - | - |  |  |  |  |
| Belgorod – Tambov | -0.445\*\*\* | 0.001 | *-0.009* | -0.263\*\*\* | 0.066 | *0.040* | -0.445\*\*\* | 0.000 | 0.445 | - | 0.445 | *0.049* |
| Tambov – Belgorod | 0.053 | 0.602 |  | 0.170 | 0.268 |  | 0.053 | 0.602 |  |  |  |  |
| Belgorod – Voronezh | -0.228 | 0.353 | *-0.068* | -0.088 | 0.594 | *0.109* | 0.228 | 0.353 | 0.581 | 0.162 | 0.581 | *0.177* |
| Voronezh – Belgorod  | 0.581\*\*\* | 0.002 |  | 0.162\* | 0.091 |  | 0.581\*\*\* | 0.002 |  |  |  |  |
| Kursk – Lipetsk | - | - | *-* | -0.337\*\*\* | 0.001 | *-* | - | - | - | 0.337 | - | *-* |
| Lipetsk – Kursk | - | - |  | -0.017 | 0.956 |  | - | - |  |  |  |  |
| Kursk – Tambov | 0.024 | 0.855 | *-0.013* | -0.008 | 0.963 | *0.085* | -0.042 | 0.791 | 0.400 | 0.468 | 0.504 | *0.098* |
| Tambov – Kursk | 0.400\*\*\* | 0.001 |  | 0.468\*\*\* | 0.001 |  | 0.504\*\*\* | 0.001 |  |  |  |  |
| Kursk – Voronezh | -0.165 | 0.457 | *-0.087* | -0.264 | 0.186 | *0.136* | 0.028 | 0.931 | 0.326 | 0.311 | 0.721 | *0.223* |
| Voronezh – Kursk | 0.326\*\* | 0.039 |  | 0.311\*\*\* | 0.004 |  | 0.721\*\* | 0.014 |  |  |  |  |
| Lipetsk – Tambov | - | - | *-* | -0.004 | 0.967 | *-* | - | - | - | 0.306 | - | *-* |
| Tambov – Lipetsk | - | - |  | 0.306\*\* | 0.027 |  | - | - |  |  |  |  |
| Lipetsk – Voronezh | -0.039 | 0.786 | *-0.102* | -0.205\*\* | 0.034 | *0.002* | 0.206\*\* | 0.045 | 0.339 | 0.205 | 0.506 | *0.104* |
| Voronezh – Lipetsk | 0.399\* | 0.067 |  | 0.041 | 0.810 |  | 0.506\*\*\* | 0.004 |  |  |  |  |
| Tambov – Voronezh | -0.726\*\*\* | 0.001 | *-0.008* | 0.179 | 0.316 | *0.053* | -0.548 | 0.111 | 0.961 | 0.920 | 0.564 | *0.061* |
| Voronezh – Tambov | 0.235\*\*\* | 0.006 |  | 0.920\*\*\* | 0.006 |  | 0.564 | 0.104 |  |  |  |  |
| (*continued*) |
| **Table S8.** (*continued*) |
| price pair | lower regime |  | middle regime / VECM parameters *a* |  | upper regime | total adjustment*b* |  |
| sp. adj. ($ρ\_{1}$) | p-value | threshold($τ\_{1}$) | sp. adj. ($ρ\_{2}$) | p-value | threshold ($τ\_{2}$) | sp. adj. ($ρ\_{3}$) | p-value | lower | middle | upper | band ofinaction *c* |
| *West Siberia* |
| Kemerovo – Altai | -0.485\*\*\* | 0.002 | *-0.059* | -0.402\*\*\* | 0.005 | *0.039* | -0.402\*\*\* | 0.005 | 0.485 | 0.402 | 0.402 | *0.098* |
| Altai – Kemerovo | -0.074 | 0.685 |  | 0.063 | 0.738 |  | 0.063 | 0.738 |  |  |  |  |
| Kemerovo – Novosibirsk | 0.012 | 0.979 | *-0.097* | -0.236 | 0.309 | *0.123* | -0.145 | 0.630 | - | 0.367 | 0.608 | *0.220* |
| Novosibirsk – Kemerovo | 0.653 | 0.140 |  | 0.367\*\*\* | 0.008 |  | 0.608\*\*\* | 0.015 |  |  |  |  |
| Kemerovo – Omsk | - | - | *-* | -0.309\*\* | 0.027 | *-* | - | - | - | 0.309 | - | *-* |
| Omsk – Kemerovo | - | - |  | 0.304 | 0.170 |  | - | - |  |  |  |  |
| Kemerovo – Tomsk | -0.411\* | 0.073 | *-0.057* | -0.149 | 0.249 | *0.062* | -0.486\* | 0.086 | 0.411 | - | 0.468 | *0.119* |
| Tomsk – Kemerovo | 0.087 | 0.776 |  | 0.269 | 0.312 |  | 0.275 | 0.483 |  |  |  |  |
| Novosibirsk – Altai | -0.401\*\* | 0.047 | *-0.168* | -0.089 | 0.468 | *0.066* | -0.295 | 0.195 | 0.401 | - | - | *0.234* |
| Altai – Novosibirsk | -0.289 | 0.151 |  | -0.137 | 0.289 |  | -0.074 | 0.737 |  |  |  |  |
| Novosibirsk – Omsk | -1.151\*\*\* | 0.001 | *-0.194* | -0.386\*\* | 0.057 | *0.132* | -0.986\*\*\* | 0.001 | - | 0.386 | 0.986 | *0.326* |
| Omsk – Novosibirsk | -0.113 | 0.719 |  | 0.093 | 0.644 |  | -0.026 | 0.938 |  |  |  |  |
| Tomsk – Novosibirsk | -0.229 | 0.407 | *-0.115* | 0.112 | 0.651 | *0.082* | 0.008 | 0.980 | 0.507 | 0.485 | 0.773 | *0.197* |
| Novosibirsk – Tomsk | 0.507\*\* | 0.013 |  | 0.485\*\*\* | 0.001 |  | 0.773\*\*\* | 0.002 |  |  |  |  |
| Tomsk – Altai | -0.074 | 0.751 | *-0.062* | -0.517\* | 0.056 | *0.008* | -0.344 | 0.129 | 0.606 | 0.517 | - | 0.070 |
| Altai – Tomsk | 0.606\*\*\* | 0.005 |  | 0.011 | 0.967 |  | 0.197 | 0.385 |  |  |  |  |
| Tomsk – Omsk | -0.277\*\* | 0.041 | *-0.015* | -0.084 | 0.956 | *0.002* | -0.114 | 0.489 | 0.708 | - | 0.646 | *0.017* |
| Omsk – Tomsk | 0.431\*\* | 0.031 |  | 0.870 | 0.574 |  | 0.646\*\*\* | 0.006 |  |  |  |  |
| Altai – Omsk | -0.590\*\* | 0.020 | *-0.147* | -0.047 | 0.723 | *0.042* | -0.386 | 0.113 | 0.590 | 0.557 | - | *0.189* |
| Omsk – Altai | 0.116 | 0.692 |  | 0.557\*\*\* | 0.002 |  | 0.270 | 0.377 |  |  |  |  |
| Tyumen – Altai | -0.836\*\*\* | 0.001 | *-0.117* | -0.710\*\*\* | 0.003 | *0.007* | -0.714\*\*\* | 0.001 | 0.836 | 1.00 | 0.902 | *0.124* |
| Altai – Tyumen | -0.356\*\*\* | 0.001 |  | 0.303\*\* | 0.021 |  | 0.188\* | 0.052 |  |  |  |  |
| Tyumen – Kemerovo | 0.069 | 0.585 | *-0.063* | 0.064 | 0.626 | *0.056* | 0.064 | 0.626 | 0.508 | 0.531 | 0.531 | *0.119* |
| Kemerovo – Tyumen | 0.508\*\*\* | 0.006 |  | 0.531\*\*\* | 0.007 |  | 0.531\*\*\* | 0.007 |  |  |  |  |
| Tyumen – Novosibirsk | -0.838\*\* | 0.017 | *-0.057* | -0.620\*\* | 0.023 | *0.063* | -0.734\* | 0.081 | 0.838 | 0.620 | 0.734 | *0.120* |
| Novosibirsk – Tyumen | 0.040 | 0.879 |  | 0.281 | 0.135 |  | 0.258 | 0.466 |  |  |  |  |
| (*continued*) |
| **Table S8.** (*continued*) |
| price pair | lower regime |  | middle regime / VECM parameters *a* |  | upper regime | total adjustment*b* |  |
| sp. adj. ($ρ\_{1}$) | p-value | threshold($τ\_{1}$) | sp. adj. ($ρ\_{2}$) | p-value | threshold ($τ\_{2}$) | sp. adj. ($ρ\_{3}$) | p-value | lower | middle | upper | band ofinaction *c* |
| Tyumen – Omsk | -1.068\*\*\* | 0.001 | *-0.089* | -0.869\*\*\* | 0.001 | *0.069* | -0.869\*\*\* | 0.001 | 0.483 | 0.869 | 0.869 | *0.158* |
| Omsk – Tyumen | -0.585\*\* | 0.053 |  | -0.222 | 0.341 |  | -0.221 | 0.341 |  |  |  |  |
| Tyumen – Tomsk | -0.995\*\*\* | 0.001 | *-0.037* | -0.748\*\*\* | 0.001 | *0.081* | 0.779\*\*\* | 0.001 | 0.995 | 0.748 | 0.779 | *0.112* |
| Tomsk – Tyumen | -0.255 | 0.202 |  | 0.097 | 0.683 |  | 0.077 | 0.752 |  |  |  |  |
| *Iowa* |
| Cedar Rapids – Emmetsburg | 0.638 | 0.023 | *-0.028* | 0.638 | 0.023 | *0.038* | 0.638 | 0.023 | - | - | - | *0.066* |
| Emmetsburg – Cedar Rapids | 0.135 | 0.637 |  | 0.135 | 0.637 |  | 0.135 | 0.637 |   |   |   |  |
| Clinton – Cedar Rapids | -0.197 | 0.759 | *-0.008* | -0.005 | 0.994 | *0.018* | -0.197 | 0.759 | - | 0.812 | - | *0.026* |
| Cedar Rapids – Clinton | 0.705 | 0.191 |  | 0.812 | 0.108 |  | 0.705 | 0.191 |   |   |   |  |
| Clinton – Davenport | - | - | *-* | -0.195 | 0.528 | *-* | - | - | - | 0.429 | - | *-* |
| Davenport – Clinton | - | - |  | 0.429 | 0.057 |  | - | - |   |   |   |  |
| Clinton – Emmetsburg | 0.117 | 0.709 | *-0.038* | 0.012 | 0.963 | *0.044* | 0.117 | 0.709 | 0.437 | - | 0.437 | *0.081* |
| Emmetsburg – Clinton | 0.437 | 0.049 |  | 0.287 | 0.150 |  | 0.437 | 0.049 |   |   |   |  |
| Eddyville – Cedar Rapids | -0.522 | 0.075 | *-0.064* | -0.559 | 0.032 | *0.032* | -0.522 | 0.075 | 0.522 | 0.559 | 0.522 | *0.096* |
| Cedar Rapids – Eddyville | 0.218 | 0.449 |  | 0.104 | 0.693 |  | 0.218 | 0.449 |   |   |   |  |
| Clinton – Muscatine | - | - | *-* | 0.138 | 0.843 | *-* | - | - | - | 0.787 | - | *-* |
| Muscatine – Clinton | - | - |  | 0.787 | 0.003 |  | - | - |   |   |   |  |
| Davenport – Cedar Rapids | 0.332 | 0.374 | *-0.123* | -0.421 | 0.031 | *0.052* | 0.332 | 0.374 | 0.726 | - | 0.726 | *0.175* |
| Cedar Rapids – Davenport | 0.726 | 0.002 |  | -0.368 | 0.071 |  | 0.726 | 0.002 |   |   |   |  |
| Davenport – Emmetsburg | -0.306 | 0.047 | *-0.077* | -0.394 | 0.039 | *0.027* | -0.332 | 0.042 | 0.306 | 0.394 | 0.332 | *0.104* |
| Emmetsburg – Davenport | -0.245 | 0.197 |  | -0.360 | 0.134 |  | -0.276 | 0.171 |   |   |   |  |
| Eddyville – Clinton | -0.634 | 0.014 | *-0.051* | -0.634 | 0.014 | *0.024* | -0.634 | 0.014 | 0.634 | 0.634 | 0.634 | *0.075* |
| Clinton – Eddyville | 0.130 | 0.603 |  | 0.130 | 0.603 |  | 0.130 | 0.603 |   |   |   |  |
| Eddyville – Davenport | 0.194 | 0.540 | *-0.079* | -0.671 | 0.005 | *0.036* | -0.683 | 0.004 | 0.715 | 0.671 | 0.683 | *0.115* |
| Davenport – Eddyville | 0.715 | 0.004 |  | -0.123 | 0.707 |  | -0.195 | 0.555 |   |   |   |  |
| Eddyville – Emmetsburg | -0.669 | 0.001 | *-0.076* | -0.627 | 0.006 | *0.028* | -0.578 | 0.012 | 0.669 | 0.627 | 0.578 | *0.103* |
| Emmetsburg – Eddyville | -0.298 | 0.305 |  | -0.337 | 0.275 |  | -0.259 | 0.386 |   |   |   |  |
| (*continued*) |
| **Table S8.** (*continued*) |
| price pair | lower regime |  | middle regime / VECM parameters *a* |  | upper regime | total adjustment*b* |  |
| sp. adj. ($ρ\_{1}$) | p-value | threshold($τ\_{1}$) | sp. adj. ($ρ\_{2}$) | p-value | threshold ($τ\_{2}$) | sp. adj. ($ρ\_{3}$) | p-value | lower | middle | upper | band ofinaction *c* |
| Eddyville – Keokuk | 0.066 | 0.847 | *-0.052* | -0.031 | 0.927 | *0.027* | 0.065 | 0.846 | 0.631 | 0.660 | 0.618 | *0.078* |
| Keokuk – Eddyville | 0.631 | 0.025 |  | 0.660 | 0.017 |  | 0.618 | 0.025 |   |   |   |  |
| Eddyville – Muscatine | -0.531 | 0.104 | *-0.024* | -0.729 | 0.056 | *0.003* | -0.546 | 0.097 | 0.531 | 0.729 | 0.546 | *0.027* |
| Muscatine – Eddyville | 0.447 | 0.126 |  | 0.243 | 0.566 |  | 0.437 | 0.145 |   |   |   |  |
| Keokuk – Clinton | -0.931 | 0.022 | *-0.104* | -0.531 | 0.009 | *0.044* | -0.045 | 0.001 | 0.931 | 0.531 | 0.045 | *0.148* |
| Clinton – Keokuk | -0.755 | 0.290 |  | -0.178 | 0.403 |  | -2.393 | 0.141 |   |   |   |  |
| Keokuk – Davenport | - | - | *-* | -0.637 | 0.017 | *-* | - | - | - | 0.637 | - | *-* |
| Davenport – Keokuk | - | - |  | 0.059 | 0.743 |  | - | - |   |   |   |  |
| Keokuk – Emmetsburg | -0.585 | 0.008 | *-0.144* | -0.401 | 0.023 | *0.030* | -0.426 | 0.012 | 0.585 | 0.401 | 0.426 | *0.174* |
| Emmetsburg – Keokuk | -0.680 | 0.019 |  | -0.233 | 0.215 |  | -0.270 | 0.142 |   |   |   |  |
| Keokuk – Muscatine | -0.823 | 0.006 | *-0.070* | -0.282 | 0.294 | *0.041* | 0.370 | 0.002 | 0.823 | - | - | *0.111* |
| Muscatine – Keokuk | -0.314 | 0.445 |  | 0.010 | 0.969 |  | -2.488 | 0.188 |   |   |   |  |
| Muscatine – Cedar Rapids | -0.554 | 0.157 | *-0.014* | -0.973 | 0.006 | *0.019* | -0.554 | 0.157 | - | 0.973 | - | *0.033* |
| Cedar Rapids – Muscatine | 0.309 | 0.467 |  | -1.316 | 0.080 |  | 0.309 | 0.467 |   |   |   |  |
| Muscatine – Davenport | 0.335 | 0.461 | *-0.094* | -0.600 | 0.008 | *0.018* | -0.600 | 0.008 | 0.570 | 0.600 | 0.600 | *0.113* |
| Davenport – Muscatine | 0.570 | 0.091 |  | -0.119 | 0.645 |  | -0.119 | 0.645 |   |   |   |  |
| Muscatine – Emmetsburg | - | - | *-* | -0.686 | 0.004 | *-* | - | - | - | 0.686 | - | *-* |
| Emmetsburg – Muscatine | - | - |  | -1.048 | 0.012 |  | - | - |   |   |   |  |
| W. Burlington – Cedar Rapids | -0.532 | 0.036 | *-0.014* | -0.676 | 0.048 | *0.032* | -0.532 | 0.036 | 0.532 | 0.676 | 0.532 | *0.046* |
| Cedar Rapids – W. Burlington | -0.023 | 0.931 |  | -0.730 | 0.108 |  | -0.023 | 0.931 |   |   |   |  |
| W. Burlington – Davenport | - | - | *-* | -0.577 | 0.014 | *-* | - | - | - | 0.577 | - | *-* |
| Davenport – W. Burlington | - | - |  | -0.006 | 0.968 |  | - | - |   |   |   |  |
| W. Burlington – Eddyville | -0.191 | 0.576 | *-0.008* | -0.473 | 0.171 | *0.003* | -0.191 | 0.576 | 0.626 | - | 0.626 | *0.011* |
| Eddyville – W. Burlington | 0.626 | 0.031 |  | 0.429 | 0.209 |  | 0.626 | 0.031 |   |   |   |  |
| W. Burlington – Emmetsburg | 0.146 | 0.499 | *-0.044* | 0.170 | 0.410 | *0.049* | 0.146 | 0.499 | 0.331 | 0.335 | 0.331 | *0.094* |
| Emmetsburg – W. Burlington | 0.331 | 0.068 |  | 0.335 | 0.052 |  | 0.331 | 0.068 |   |   |   |  |
| W. Burlington – Keokuk | 5.509 | 0.065 | *-0.051* | -0.111 | 0.796 | *0.025* | -0.070 | 0.872 | - | - | - | *0.076* |
| Keokuk – W. Burlington | -0.359 | 0.012 |  | 0.575 | 0.141 |  | 0.610 | 0.111 |   |   |   |  |
| (*continued*) |
| **Table S8.** (*continued*) |
| price pair | lower regime |  | middle regime / VECM parameters *a* |  | upper regime | total adjustment*b* |  |
| sp. adj. ($ρ\_{1}$) | p-value | threshold($τ\_{1}$) | sp. adj. ($ρ\_{2}$) | p-value | threshold ($τ\_{2}$) | sp. adj. ($ρ\_{3}$) | p-value | lower | middle | upper | band ofinaction *c* |
| W. Burlington – Muscatine | -0.593 | 0.102 | *-0.032* | -0.595 | 0.100 | *0.013* | -0.593 | 0.102 | 0.593 | 0.595 | 0.593 | *0.045* |
| Muscatine – W. Burlington | -0.108 | 0.789 |  | -0.116 | 0.774 |  | -0.108 | 0.789 |   |   |   |  |
| *North Carolina* |
| Candor – Creswell | -0.143 | 0.729 | *-0.081* | -0.276 | 0.339 | *0.032* | -0.214 | 0.492 | 0.655 | - | - | *0.112* |
| Creswell – Candor | 0.655 | 0.107 |  | 0.312 | 0.383 |  | 0.357 | 0.331 |   |   |   |  |
| Cofield – Candor | -0.244 | 0.221 | *-0.097* | -0.047 | 0.799 | *0.029* | -0.244 | 0.221 | - | - | - | *0.126* |
| Candor – Cofield | -0.062 | 0.743 |  | 0.128 | 0.422 |  | -0.062 | 0.743 |   |   |   |  |
| Cofield – Creswell | - | - | *-* | 0.003 | 0.998 | *-* | - | - | - | 0.574 | - | *-* |
| Creswell – Cofield | - | - |  | 0.574 | 0.003 |  | - | - |   |   |   |  |
| Laurinburg – Candor | -0.097 | 0.762 | *-0.038* | -0.097 | 0.762 | *0.006* | -0.316 | 0.279 | - | - | - | *0.045* |
| Candor – Laurinburg | 0.348 | 0.230 |  | 0.348 | 0.230 |  | 0.072 | 0.813 |   |   |   |  |
| Laurinburg – Creswell | -0.647 | 0.010 | *-0.050* | 0.082 | 0.841 | *0.036* | -0.685 | 0.015 | 0.647 | - | 0.685 | *0.086* |
| Creswell – Laurinburg | -0.211 | 0.455 |  | 0.416 | 0.183 |  | -0.138 | 0.674 |   |   |   |  |
| Laurinburg – Roaring River | -0.238 | 0.337 | *-0.075* | -0.252 | 0.324 | *0.003* | -0.515 | 0.039 | - | - | 0.515 | *0.079* |
| Roaring River – Laurinburg | 0.204 | 0.377 |  | 0.150 | 0.540 |  | -0.048 | 0.861 |   |   |   |  |
| Laurinburg – Statesville | 0.126 | 0.717 | *-0.021* | 3.804 | 0.002 | *0.002* | 0.126 | 0.717 | - | - | - | *0.023* |
| Statesville – Laurinburg | 0.254 | 0.397 |  | 0.972 | 0.002 |  | 0.254 | 0.397 |   |   |   |  |
| Roaring River – Candor | -0.284 | 0.448 | *-0.029* | -0.284 | 0.448 | *0.026* | -0.284 | 0.448 | - | - | - | *0.055* |
| Candor – Roaring River | 0.469 | 0.205 |  | 0.469 | 0.205 |  | 0.469 | 0.205 |   |   |   |  |
| Roaring River – Cofield | 0.111 | 0.464 | *-0.070* | 0.183 | 0.296 | *0.028* | 0.111 | 0.464 | - | - | - | *0.098* |
| Cofield – Roaring River | -0.289 | 0.133 |  | -0.206 | 0.316 |  | -0.289 | 0.133 |   |   |   |  |
| Roaring River – Creswell | - | - | *-* | -0.066 | 0.997 | *-* | - | - | - | 0.630 | - | *-* |
| Creswell – Roaring River | - | - |  | 0.630 | 0.007 |  | - | - |   |   |   |  |
| Roaring River – Statesville | -0.194 | 0.484 | *-0.014* | -0.212 | 0.441 | *0.003* | -0.194 | 0.484 | - | - | - | *0.017* |
| Statesville – Roaring River | 0.306 | 0.307 |  | 0.275 | 0.363 |  | 0.306 | 0.307 |   |   |   |  |
| Statesville – Candor | -0.260 | 0.510 | *-0.024* | -0.232 | 0.553 | *0.015* | -0.260 | 0.510 | - | - | - | *0.039* |
| Candor – Statesville | 0.120 | 0.755 |  | 0.139 | 0.710 |  | 0.120 | 0.755 |   |   |   |  |
| (*continued*) |
| **Table S8.** (*continued*) |
| price pair | lower regime |  | middle regime / VECM parameters *a* |  | upper regime | total adjustment*b* |  |
| sp. adj. ($ρ\_{1}$) | p-value | threshold($τ\_{1}$) | sp. adj. ($ρ\_{2}$) | p-value | threshold ($τ\_{2}$) | sp. adj. ($ρ\_{3}$) |  | lower | middle | upper | band ofinaction *c* |
| Statesville – Cofield | -0.161 | 0.409 | *-0.057* | -0.161 | 0.409 | *0.018* | -0.161 | 0.409 | - | - | - | *0.076* |
| Cofield – Statesville | 0.052 | 0.775 |  | 0.052 | 0.775 |  | 0.052 | 0.775 |   |   |   |  |
| Statesville – Creswell | - | - | *-* | -0.021 | 0.978 | *-* | - | - | - | 0.596 | - | *-* |
| Creswell – Statesville | - | - |  | 0.596 | 0.016 |  | - | - |   |   |   |  |

Note: † to make speed of adjustment parameters of different frequencies comparable we convert them from weekly to biweekly frequency by using following formula $|ρ|^{biweekly}=1-(1-|ρ|^{weekly})^{2}$ for Iowa and North Carolina. Parameters for North Caucasus and West Siberia are by itself estimated on biweekly level. *a*parametersfrom the linear VECM are not regime-specific and thresholds are not estimated. Thus, linear VECM estimates are presented in the middle regime column. *b*total adjustment in one regime is calculated as the sum of the absolute value of the respective regime-specific speed of adjustment parameters of the TVECM significant at least 10% level. *c* the band of inaction is given as the difference between the absolute value of the upper and lower threshold. The hyphen (-) = not applicable. \* p<0.10, \*\* p<0.05, \*\*\* p<0.01.

**Table S9.** Additional production potential in Russia at the regional level

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Economic region | Sownarea | Observed yield | Yield gap | Abandoned land | Intensification 80% | Recultivation 15% | Intensification 80% & recultivation 15% |
| Measurement unit | Mio ha | t/ha | t/ha | Mio ha | Mio t (% of total) | Mio t (% of total) | Mio t (% of total) |
| Column | A | B | D | E | F = (A x D) x 0.8 | G = (B x E) x 0.15 | H = F + G |
| Source | Swinnen *et al*. (2017) | Swinnen *et al*. (2017) | Swinnen *et al*. (2017) | Lesiv *et al*. (2018) | own calculation | own calculation | own calculation |
| Black Earth | 2.21 | 2.95 | 1.99 | 2.19 | 8.69 (13%) | 0.96 (7%) | 4.10 (9%) |
| Central | 1.37 | 2.14 | 3.04 | 9.53 | 5.51 (8%) | 3.00 (21%) | 6.20 (14%) |
| North Caucasus | 5.13 | 2.52 | 2.75 | 4.39 | 17.25 (26%) | 1.70 (12%) | 6.75 (15%) |
| Ural | 4.54 | 1.33 | 2.56 | 10.47 | 12.21 (18%) | 2.01 (14%) | 10.66 (24%) |
| Volga | 3.75 | 1.78 | 1.56 | 8.76 | 10.99 (16%) | 2.29 (16%) | 7.02 (16%) |
| West Siberia | 3.76 | 1.49 | 2.13 | 7.73 | 5.98 (9%) | 1.13 (8%) | 5.02 (11%) |
| Other regions | 1.66 | 1.90 | 2.56 | 13.08 | 5.97 (9%) | 3.37 (23%) | 4.71 (11%) |
| **Ural & West Siberia** | **8.30** | **1.41** | **2.35** | **18.20** | **18.19 (27%)** | **3.14 (22%)** | **15.68 (35%)** |
| Total Russia | 22.43 | 1.99 | 2.47 | 56.14 | 66.60 (100%) | 14.46 (100%) | 44.47 (100%) |

Note: Data shown in columns A–E is provided by Florian Schierhorn.

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