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STUDIES ON THE AGRICULTURAL AND FOOD SECTOR IN TRANSITION ECONOMIES

Miranda Svanidze

SPATIAL MARKET EFFICIENCY OF GRAIN MARKETS IN THE POST-SOVIET COUNTRIES AND IMPLICATIONS FOR GLOBAL FOOD SECURITY

Leibniz Association

Leibniz Institute of Agricultural Development
in Transition Economies

Studies on the Agricultural and Food Sector in Transition Economies

Edited by

Leibniz Institute of Agricultural Development in Transition Economies

IAMO

Volume 96

Bibliografische Information der Deutschen Nationalbibliothek

Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über http://dnb.dnb.de abrufbar.

Bibliographic information published by Die Deutsche Nationalbibliothek

The German National Library (DNB) lists the publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the internet at: http://dnb.dnb.de.

This thesis was accepted as a doctoral dissertation in fulfillment of the requirements for the degree "doctor agriculturarum" by the Faculty of Natural Sciences III at Martin Luther University Halle-Wittenberg on 09.04.2019.

Date of oral examination: 21.10.2019
Supervisor and Reviewer: PD Dr. Linde Götz together with Prof. Dr. Dr. h.c. Thomas Glauben
Co-Reviewer: Prof. Dr. Barry K. Goodwin

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ISSN 1436-221X
ISBN 978-3-95992-096-4

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Printed with the support of the German Academic Exchange Service.

IAMO 2020

ACKNOWLEDGEMENTS

The research for this doctoral dissertation would not have been possible without the generous financial support from the German Academic Exchange Service (DAAD) and the Volkswagen Foundation for the project "The Global Food Crisis – Impact on Wheat Markets and Trade in the Caucasus and Central Asia and the Role of Kazakhstan, Russia and Ukraine".

I am grateful to my supervisor, Prof. Dr. Thomas Glauben, for not only his valuable suggestions and comments, but also for providing an excellent work environment at the Leibniz Institute of Agricultural Development in Transition Economies (IAMO), which enabled me to undertake this research.

I would like to express my sincere gratitude to my enthusiastic supervisor, PD Dr. Linde Götz, for her continuous support and excellent guidance since day one of this research and thesis. I am very grateful for her profound discussions and advice that helped me to sharpen my research ideas and broaden my perspective so I could view the research topics from different perspectives.

Beyond my supervisors, many people have helped with this thesis. I would like to single out Prof. Dr. Barry Goodwin and Prof. Dr. Nicholas Piggott, who provided corn price data and wonderful advice, especially for the methodological part of my PhD work. I additionally thank the Russian Grain Union for providing wheat price data on regional level. In addition, Daniyar Minnullin, a scientific assistant at IAMO, provided invaluable contributions by helping with the time-consuming econometric estimations with several hundred model runs.

I am greatly indebted to Prof. Dr. Dr. h.c. mult. Ulrich Koester, whom I first met during my master's degree studies in Georgia. Without his convincing talk pointing me to pursue a PhD degree in agricultural economics, my professional path would probably have never crossed with IAMO.

I am thankful to all the members of administrative staff at IAMO who always made sure that all the organizational and bureaucratic issues were solved. Special thanks to Antje Elsner, the driving force at the Department of Agricultural Markets, who helped out with everything, as she always does. I also owe a special thanks to all the friends inside and outside of IAMO for the laughter and good cheer they brought into my PhD-full life for several years now.

I would like to generously thank my husband Giorgi and my daughter Emily for bringing bright colors and emotional fulfillment into my life. I owe my sincere gratitude to my mother, Irma, for her unconditional love and unwavering belief in me, and to my sister, Tako, who has been my best friend since my entrance into this world. This thesis is dedicated to the loving memory of my beloved father, Ilia.

ABSTRACT

This doctoral thesis studies the spatial market efficiency of wheat markets in selected post-Soviet countries; particularly in Russia, the largest wheat exporting country in the world, and in the grain import-dependent countries of Central Asia and the South Caucasus.

Increased grain production in the Black Sea region, and in Russia specifically, is crucial for meeting increasing global agricultural demand and global food security. Grain production in Russia could be boosted by increasing grain production efficiency and also by re-cultivating formerly abandoned agricultural land. However, to increase Russia's role in global wheat supply, additional grain production potential has to coincide with improving the country's grain export perspectives. On the other hand, the realization of Russia's export capacity largely depends on the performance of its regional grain markets domestically.

Using price transmission and panel data analyses in a comparative context, this study finds the wheat market of Russia segmented, with the primary wheat export region poorly integrated into the domestic market. This thesis also demonstrates that regional wheat market integration in Russia is relatively low and heterogeneous and trade costs are relatively high compared to the USA, mostly due to large distances between grain producing regions. In addition, by including the USA as benchmark country, a comparative approach enables a more comprehensive assessment of the spatial market efficiency of the wheat market in Russia. The results also provide evidence on the dissimilarity of the underlying fundamental mechanism of market integration between Russia and the USA. In Russia, the physical trade of wheat mainly fosters market integration at the interregional level, whereas in the USA, in addition to physical trade, information flows induced by commodity futures markets play a major role in the regional grain market integration.

The distinction between grain production and export potential, especially for markets located in peripheral regions of Russia, is essential to

correctly identify Russia's future role for global food security. As a general conclusion, besides raising agricultural production potential it is also essential to strengthen spatial market efficiency in the agricultural sector to boost agricultural export potential and to increase global food security. To improve Russian wheat market efficiency, substantial investments in the grain market and transportation infrastructure, upgraded market information services, and the development of commodity futures markets are required.

Additionally, the wheat export ban implemented in 2010/11 in Russia resulted in increased market instability and high wheat trade transaction costs within the country. Export restrictions negatively affect the development of the commodity futures markets and increase market instability, which discourage investments in grain production and hence, has a detrimental effect on the realization of wheat production potential.

From the perspective of net wheat import-dependent countries, this thesis investigates wheat price relationships between the import-dependent countries in Central Asia and the South Caucasus and the Black Sea wheat exporters to assess the wheat market efficiency in Central Asia and the South Caucasus that is also crucial for their national food security. This thesis finds evidence of a strong influence of trade costs on market integration in Central Asia, while those costs are of minor importance in the South Caucasus. In addition, wheat price volatility is substantially higher in the wheat importing countries of Central Asia compared to the South Caucasus. Weak integration of Central Asia's wheat markets with the world trade system, accompanied by high transportation costs and volatile wheat prices, indicates low resilience of the food system and rather high vulnerability against food insecurity. To foster market functioning, investments in transportation infrastructure, but also the elimination of informal payments, are fundamental for reducing grain trade costs in Central Asia. In addition, due to their landlocked position, the countries of Central Asia, as well as Armenia and Azerbaijan in the South Caucasus, should complement their trade enhancing policies with agricultural policies aimed at boosting domestic wheat production and increasing wheat self-sufficiency.

ZUSAMMENFASSUNG

Diese Arbeit untersucht die räumliche Markteffizienz von Getreidemärkten in ausgewählten Ländern der ehemaligen Sowjetunion, insbesondere Russland, dem größten Getreideexportland weltweit, sowie in vom Getreideimport abhängigen Ländern Zentralasiens und des Südkaukasus.

Die erhöhte Getreideproduktion in der Schwarzmeerregion, und in Russland speziell, spielt eine entscheidende Rolle, um den wachsenden weltweiten Bedarf an Agrarprodukten und dem Problem der Ernährungssicherheit zu begegnen. Damit Russland einerseits seine Rolle in der globalen Weizenproduktion jedoch ausfüllen kann, ist die Mobilisierung zusätzlicher Produktionspotenziale zusammen mit einer Verbesserung der Exportmöglichkeiten für Getreide notwendig. Andererseits hängt die Ausschöpfung der Exportmöglichkeiten entscheidend von den inländischen regionalen Getreidemärkten ab.

Auf der Grundlage von Preistransmissions- und Paneldatenuntersuchung in einem vergleichenden Kontext wird in dieser Studie festgestellt, dass der Weizenmarkt Russlands segmentiert ist und die primäre Getreide-Exportregion schwach in den Inlandsmarkt integriert ist. Diese Arbeit zeigt auch, dass die regionale Integration des Weizenmarktes in Russland teilweise relativ gering ist und die Handelskosten im Vergleich zu den USA relativ hoch sind, was vor allem auf große Entfernungen zwischen den Getreide produzierenden Regionen zurückzuführen ist. Darüber hinaus ermöglicht ein vergleichender Ansatz durch die Einbeziehung der USA eine umfassendere Bewertung der räumlichen Effizienz des Weizenmarktes in Russland. Die Ergebnisse liefern auch Hinweise auf die Unterschiede des zugrunde liegenden grundlegenden Mechanismus der Marktintegration zwischen Russland und den USA. In Russland fördert der physische Handel mit Weizen hauptsächlich die Marktintegration auf interregionaler Ebene, während in den USA neben dem physischen Handel auch die von den Warenterminmärkten induzierten

Informationsflüsse eine wichtige Rolle bei der regionalen Integration der Getreidemärkte spielen.

Die Unterscheidung zwischen Getreideproduktions- und Exportpotenzial, insbesondere für Märkte in peripheren Regionen Russlands, ist von wesentlicher Bedeutung, um die künftige Rolle Russlands für die globale Ernährungssicherheit richtig einzuschätzen. Generell ist es neben der Erhöhung des landwirtschaftlichen Produktionspotenzials auch von wesentlicher Bedeutung, die räumliche Markteffizienz im Agrarsektor zu stärken, um das landwirtschaftliche Exportpotenzial zu steigern und so die globale Ernährungssicherheit zu verbessern. Um die Effizienz des russischen Weizenmarktes zu steigern, sind umfangreiche Investitionen in den Getreidemarkt und die Verkehrsinfrastruktur, verbesserte marktbezogene Informationsdienste und die Entwicklung von Rohstoff-Terminmärkten erforderlich.

Darüber hinaus führte das 2010/11 in Russland verhängte Getreideexportverbot zu einer erhöhten Marktinstabilität und hohen Transaktionskosten im Getreidehandel innerhalb des Landes. Exportbeschränkungen beeinträchtigen die Entwicklung der Warenterminmärkte und erhöhen die Marktinstabilität, wodurch Investitionen in die Getreideproduktion gehemmt werden und sich somit nachteilig auf die Realisierung des Weizenproduktionspotenzials auswirken.

Aus der Sicht vom Weizenimport abhängiger Länder untersucht diese Arbeit die Zusammenhänge der Weizenpreise zwischen den importabhängigen Ländern in Zentralasien und dem Südkaukasus und den Schwarzmeer-Weizenexportländern, um die Effizienz des Weizenmarktes in Zentralasien und dem Südkaukasus zu ermitteln, was für die jeweilige nationale Ernährungssicherung entscheidend ist. Diese Arbeit zeigt einen starken Einfluss der Handelskosten auf die Marktintegration in Zentralasien auf, während diese Kosten im Südkaukasus von geringer Bedeutung sind. Darüber hinaus ist die Volatilität der Weizenpreise in den Weizenimportländern Zentralasiens im Vergleich zum Südkaukasus deutlich höher. Die schwache Integration der zentralasiatischen Weizenmärkte in das Welthandelssystem, begleitet von hohen Transportkosten und volatilen Weizenpreisen, deutet auf eine geringe Widerstandsfähigkeit des Ernährungssystems und eine eher hohe Anfälligkeit für Ernährungsunsicherheit hin. Um das Funktionieren des Marktes zu fördern, sind Investitionen in die Verkehrsinfrastruktur, aber auch der Wegfall inoffizieller Zahlungen, von grundlegender Bedeutung für die Senkung der Transaktionskosten des Getreidehandels in Zentralasien. Darüber hinaus sollten die Länder Zentralasiens sowie Armeniens und Aserbaidschans im Südkaukasus aufgrund ihrer Binnenlage ihre handelsfördernde Politik durch eine Agrarpolitik ergänzen, die darauf abzielt, die einheimische Weizenproduktion zu steigern und die Selbstversorgung mit Weizen zu erhöhen.

TABLE OF CONTENTS

LIST OF TABLES

TABLES IN APPENDIXES

LIST OF FIGURES

FIGURES IN APPENDIXES

1 INTRODUCTION

1.1 PROBLEM STATEMENT AND RESEARCH QUESTIONS

Global population, and accordingly global food demand, are expected to increase in the coming decades (FAO, 2017). The world's population is estimated to grow to almost 10 billion by 2050 (UN-DESA, 2017). Nearly 30% of this growth is predicted to be concentrated in the South and Central Asian and the Middle East and North African (MENA) countries. These regions have intensive wheat consumption, but also little prospects of satisfying additional domestic demand by increasing their own grain production (OECD/FAO, 2018).

In contrast, the importance of the Black Sea region in the global wheat trade, and therefore in global food security, is expected to increase in the future (Bokusheva and Hockmann, 2006; Lioubimtseva and Henebry, 2012). Grain production in the major grain exporting countries of the Black Sea region can be increased by improving grain production efficiency and also by re-cultivating formerly abandoned agricultural land (Fellmann et al., 2014; Schierhorn et al., 2014; Swinnen et al., 2017). Further, in consideration of declining population forecasts for the Black Sea region (UN-DESA, 2017), domestic grain consumption is foreseen to remain stable, hypothetically qualifying all additionally produced grain for international exports (Deppermann et al., 2018). As Southern and Central Asian and MENA countries are located in close vicinity to the Black Sea region, it is also highly likely that, in the future, these countries will rely on grain imported from the Black Sea region.

Historically, the Black Sea countries—Russia, Kazakhstan, and Ukraine—have not been grain exporting countries; rather quite the opposite. However, together with Kazakhstan and Ukraine, Russia, has become an increasingly significant player on global wheat markets over the past two decades. Since the dissolution of the Soviet Union in 1991, these post-soviet countries began transforming from centrally planned to market economies.[1] This change in market structure has been accompanied by increased wheat production and consequently higher exports to the world market, especially since the early 2000s (Fig. 1.1.1).

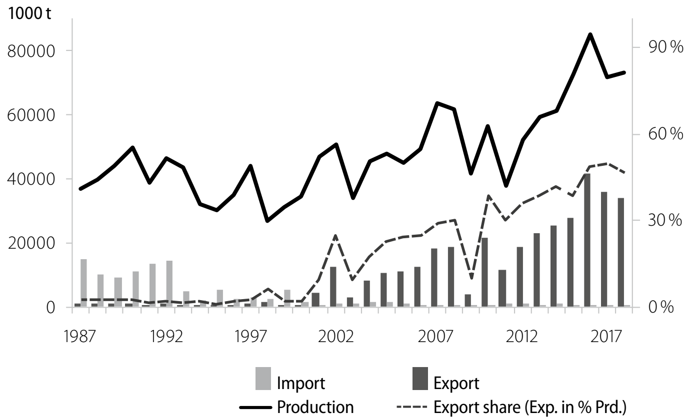

Fig. 1.1.1: Wheat production and trade in Russia, 1987–2018

Source: USDA-PSD (2018)

Among the post-Soviet states, Russia is the largest grain producing and exporting country. Between 2000 and 2017, Russia increased its wheat production from 35 to 85 million tons and wheat exports from 0.7 to 42 million tons (USDA-PSD, 2018). Since 2017, Russia has been the largest wheat exporter to the world market, even though it is the fourth largest wheat producer in the world after the European Union, China, and India (USDA-FAS, 2018). Specifically, Russian wheat exports amounted to 15% and 22% of global wheat exports in 2016 and 2017, respectively (USDA-WASDE, 2017).

1 The Soviet Union dissolved into 15 independent states: Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine and Uzbekistan.

Weather conditions strongly influence grain production in Russia, resulting in large temporary variations across regions and years. For instance, total wheat production significantly decreased in 2010 and 2012, when a critical drought hit wheat-producing regions in Russia (Fig 1.1.1). Unusually low harvest in the Russia's key crop growing areas in 2010 also prompted the Russian government to impose a wheat export ban on August 15, 2010. Initially, the ban was introduced to last until December 2010, but it was subsequently prolonged until July 2011. This export ban aimed to decrease domestic prices and maintain adequate availability of grain within Russia.

Hence, increased grain production in the Black Sea region, and particularly in Russia, is crucial for meeting increasing agricultural demands and global food security. However, grain production is spread across large geographic areas in Russia and marked by long travel distances to export markets. Thus, not only additional grain production should be increased, but the country's export potential also has to be improved in order to increase Russia's role in global wheat exports. At the same time, the realization of Russia's export capacity largely depends on the performance of its regional grain markets domestically. That requires a spatially efficient grain market ensuring complete and quick transmission of price changes from the grain exports to the production regions.

Determined by the availability of food products and the level of end consumer food prices on domestic markets, the efficiency of agricultural and food markets in net import-dependent countries and their integration into the world market system is also crucial for national food security (FAO, 2009). Food prices affect the nutritional status of poor households especially, which spend large shares of their income on food (Matz et al., 2015). Especially, the shares of dietary calories derived solely from wheat are the largest (between 35%–55%) in the countries of Central Asia and the South Caucasus, which gives additional emphasis to the importance of well-functioning domestic grain markets for food security in these regions (FAOSTAT, 2013).

Therefore, investigating the functioning of grain markets in the Black Sea region and their derived impact on the wheat-import dependent countries in Central Asia and the South Caucasus is at the core of this doctoral thesis. More specifically, this thesis focuses on the following research objectives: (1) to assess the spatial market efficiency of grain markets in Russia from a regional perspective; (2) to identify the factors determining spatial market efficiency of Russian grain markets; as well as (3) to examine the effect of the 2010/11 wheat export ban on the domestic price relationships in Russia. In addition, this thesis also (4) extends the analysis of spatial market efficiency in wheat-importing countries and analyses how wheat prices observed at Central Asian wheat markets of Kyrgyzstan, Tajikistan, and Uzbekistan and the South Caucasian wheat markets of Azerbaijan, Armenia, and Georgia relate to prices of the Black Sea wheat export markets (Russia, Ukraine, and Kazakhstan) and world markets (France and the USA).

1.2 STRUCTURE AND OUTLOOK OF THE DISSERTATION

Four articles grouped into three sections constitute the central elements of this dissertation. Table 1.2.1 lists the titles of all of the research contributions. The first group (chapter 2) combines two articles addressing the performance of grain markets in Russia, a large country with rapidly growing grain exports to the world market, and its implications for global food security, whereas chapter 3 considers the domestic price effects of export restrictions by examining the effects of the 2010/11 wheat export ban on domestic price relationships in Russia. Chapter 4 addresses the spatial efficiency of grain markets in the net grain-importing countries in Central Asia and the South Caucasus, which heavily rely on wheat imports from the Black Sea region.

Table 1.2.1: List of research contributions

Chapter	Authors	Title	Publication outlet
2	**Measurement and determinants of spatial market efficiency of grain markets in Russia and global food security**		
2.1	Svanidze, M. and Götz, L.	Spatial market efficiency of grain markets in Russia and global food security: A comparison with the USA	Global Food Security (GFS-2018–161, under review)
2.2	Svanidze, M. and Götz, L.	Determinants of spatial market efficiency of grain markets in Russia: A comparison with the USA	Food Policy (FOOD-POLICY_2019_123, under review)
3	**The influence of the 2010/11 export ban on spatial market efficiency of grain markets in Russia**		
3.1	Svanidze, M., Götz, L., and Serebrennikov, D.	The influence of the 2010/11export ban on the spatial market efficiency of grain markets in Russia	Agribusiness: An International Journal (AGR-19-0047, initial submission)
4	**Food security and the functioning of wheat markets in Central Asia and the South Caucasus**		
4.1	Svanidze, M., Götz, L., Djuric, I., and Glauben, T.	Food security and the functioning of wheat markets in Central Asia and the South Caucasus: A comparative price transmission analysis	Food Security (FOSE-D-18-00119R1, revised and resubmitted)

Measurement and determinants of spatial market efficiency of grain markets in Russia and global food security

The article "*Spatial market efficiency of grain markets in Russia and global food security: A comparison with the USA*" studies the spatial market efficiency of the Russian grain markets and explore how fast price shocks from one production region are transmitted to the other regions within the country.

This study addresses the spatial market efficiency of the grain markets in Russia from a regional perspective. Following a price transmission approach, it focuses on the six primary grain production regions in Russia (Fig. 1.2.1) and measure their integration among each other. The study investigates wheat price relationships between different grain production regions characterized by large distances and within selected grain production regions (North Caucasus and West Siberia) with relatively small distances.

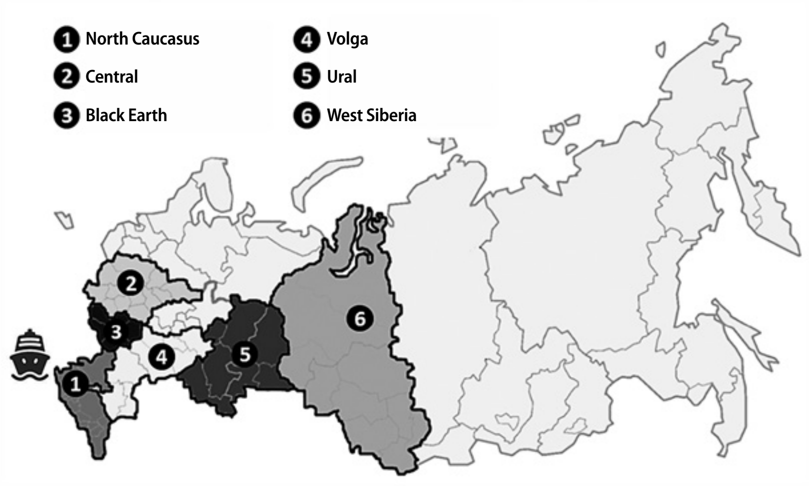

Fig. 1.2.1: Map of grain producing economic regions of Russia

Source: Own elaboration

In Russia, North Caucasus is the primary production region, which almost exclusively supplies wheat to the world market, while its role in the domestic trade is rather limited. North Caucasus accounts for almost 50% of Russia's total wheat production and 80% of total wheat exports. In contrast, Ural and West Siberia are far away not only from the world market, with the distance to the Black Sea ports amounting to 4000 kilometers, but also the grain consumption regions within Russia. In particular, Moscow is about 2000–3000 kilometer apart. In particular, West Siberia, which is the second largest grain producing region, exports only 1%–5% of its total wheat production to the world markets. Wheat produced in West Siberia is mainly consumed within the region or delivered to the neighboring region Ural.

Rail and road transport are the primary means of wheat transportation in Russia. Grain transportation tariffs are generally low in Russia (AEGIC, 2016). Nonetheless, overall transport costs are high, largely due to inadequate and outdated transport infrastructure and logistics, which negatively influence regional wheat trade volumes within Russia (Renner et al., 2014). In addition to high transport costs, grain markets in Russia are also characterized by high business and market risk (PWC, 2015). Trade costs are especially high due to the difficulty of enforcing contracts and unforeseen policy interventions for the grain markets (Götz et al. 2016, 2013).

Most studies on Russia's grain market to-date have focused on estimating Russia's capacity to increase its grain production via improvements in grain yields; expansion of agricultural land or changes in climatic conditions (for an overview see Schierhorn et al., 2014 and Swinnen et al., 2017); or assessed the effect of trade policy interventions on the performance of domestic grain markets (Götz et al., 2013, 2016). This paper adds to this literature by focusing on the importance of spatially efficient markets for transforming Russia's grain production potential into grain export potential. In addition, this study uses a Threshold Vector Error Correction Model (TVECM) with a novel Bayesian estimator of thresholds (Greb et al., 2014) to explicitly account for trade costs, which are very important for correctly identifying and measuring market integration (Goodwin and Piggott, 2001).

Another novelty of this study is its comparative approach by introducing an empirical benchmark into the analysis. A comparative approach might permit a more comprehensive interpretation of the estimated parameters, which, on their own, enable judging how well a market is functioning to a limited degree only. The study tackles this issue by investigating markets in "target" and "benchmark" countries within a similar modeling approach by directly comparing the estimated model parameters. For this purpose, the wheat market of Russia is analyzed in contrast to the corn market of the USA by assuming that the corn market of the USA is one of the most efficient grain markets in the world and serves as an empirical benchmark (rather than a theory-based benchmark) for assessing the efficiency of the Russian wheat market. Comparing the values of the estimated model parameters obtained for Russia with the USA, the degree of spatial market efficiency of the Russian wheat market is measured against the maximum degree of efficiency obtainable for grain markets in an empirical context.

While the first article analyzes the efficiency of the spatial grain markets in Russia and discusses prospects for transforming additional grain production into export potential, the second article, "*Determinants of spatial market efficiency of grain markets in Russia: A comparison with the USA*", aims to shed light on the underlying mechanism of market integration in Russia and identifies the influencing factors responsible for the functioning of the Russian wheat market. Firstly, a price transmission approach is used to obtain the quantitative measure of the grain market integration in Russia and the USA, followed by estimating a random effects panel data model to study the influence of various factors on the degree of market integration. Based on the results policy implications on how the functioning of the Russian wheat market could be improved are suggested.

Russia bears large additional grain production potential, especially in the remote regions (Swinnen et al., 2017). However, the additional wheat production potential not only has to be mobilized but also has to be transformed into additional export potential to further increase Russia's importance for global wheat exports and hence, for global food security. This requires a spatially efficient domestic grain market, ensuring comprehensive and quick transmission of price changes from the grain export to the grain production regions.

For the analysis of the grain market of Russia, the study employs a unique data set of weekly prices of wheat of class three (Ruble/ton) (Fig. 1.2.2).

However, the regional price relationships in Russia are not stable, but rather differ from marketing year to marketing year. Due to the common harvest shortfalls in Russia and thus the large variation in regional grain production, the size and direction of trade flows between surplus and deficit regions also vary strongly (Götz et al., 2016). This implies that the

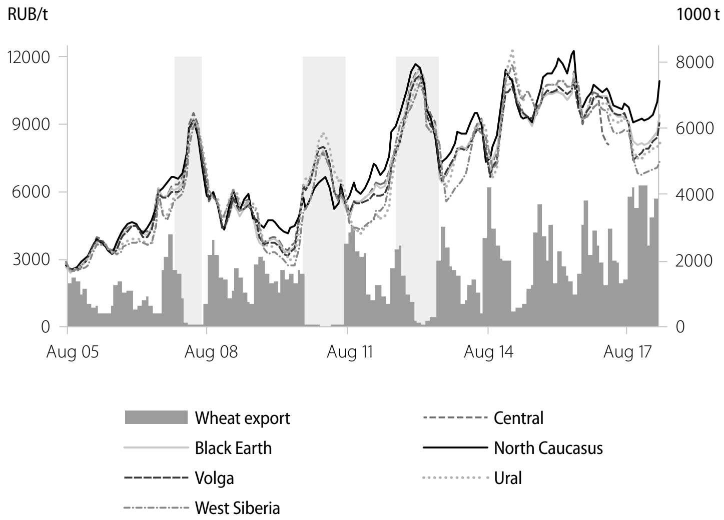

Fig. 1.2.2: Development of regional wheat prices in Russia during 2005–2013

Note: The bold area on the graph represents the periods of export tax (Nov 2007–May 2008), export ban (Aug 2010–Jul 2011) and draught season (2012–2013).

Source: Russian Grain Union (2014), GTIS (2013)

interregional price relationships, which are depicted in the price transmission model, are not stable, and thus parameter estimates may not be constant, indicating that the data generating process differs from one marketing year to another; respectively, requiring to estimate the price transmission model for Russia based on one marketing year only, which is characterized by relatively stable price relationships. Therefore, the price transmission elasticities estimated for every price pair on a yearly basis provide a measure of market integration, which enter the unobserved effects panel data model as a dependent variable. To investigate the influence of various market characteristics on the degree of market integration, the unobserved effects model is estimated within a panel data analysis.

This study, as the previous one, follows a comparative approach and investigates the wheat market of Russia compared to the corn market of the USA. Similar to wheat in Russia, corn is also a primarily produced grain in the USA and generally used as a fodder crop. However, large quantities of wheat are transported over long distances in Russia, whereas livestock farms and corn processing facilities such as ethanol plants in the USA are concentrated in the main corn production regions (with the exception of California and Texas), ensuring small transport distances (Haddad et al., 2010).

Market transparency of grain markets is generally high in the USA, where large information flows are induced by the heavy engagement of farmers and traders in commodity futures exchanges. US farmers and grain buyers regularly participate in futures markets to hedge price risk and discover market prices (Mattos, 2017). In addition, many private agricultural organizations provide high-frequency market and price information, which is used by farmers to choose locations and traders to sell their grains (Congressional Research Service, 2006). In contrast, commodity futures markets in Russia are rudimentarily developed due to the unstable market environment, a lack of futures trading skills, and low levels of trust among financial market participants (FAO, 2011). Specifically, wheat export controls have heavily increased uncertainty and are seen as one of the primary factors hampering the development of the commodity futures markets in Russia. For that reason, grain commodity exchanges in Russia mainly serve as a centralized platform for spot transactions rather than fully functional futures markets.

The influence of the 2010/11 export ban on spatial market efficiency of grain markets in Russia

Even though the first two articles more or less exhaustively explore the spatial efficiency of domestic grain markets in Russia, the effect of export restrictions remains yet unaccounted for. The article "*The influence of the 2010/11 export ban on the spatial market efficiency of grain markets in Russia*" studies the effect of the wheat export ban imposed by the Russian government between August 2010 and July 2011 on domestic price relationships within Russia. The research question is addressed within a price transmission framework and the spatial integration of wheat markets in Russia during the export ban period (2010/11) is compared to the open trade regime (2009/10).

The effect of wheat export restrictions in Russia has already been investigated with a price transmission approach by Götz et al. (2013; 2016). They find a rather low price dampening effect of the 2007/08 export tax in Russia during the global food price crisis and a strong regional variation in the price dampening effects of the 2010/11 wheat export ban, varying between 35% and 67%. Both of their studies focus on the relationship between the world market price and prices in the Russian wheat market to identify the price dampening effect of the export controls. However, this study investigates the influence of the 2010/11 export ban on domestic price relationships solely between the grain producing regions of Russia. A further novelty of this study is that by using a TVECM, any possible effects of the export ban on transaction costs are also assessed. In this regard, this article complements the study findings of the first article of this dissertation *"Spatial market efficiency of grain markets in Russia and global food security: A comparison with the USA"*; however, it covers a time period during which export to the world market was restricted.

Food security and the functioning of wheat markets in Central Asia and the South Caucasus

Understanding how and to what extent wheat market developments in small and open economy countries depend on their integration in the world grain markets is a primary focus of the fourth research contribution: "*Food security and the functioning of wheat markets in Central Asia and the South Caucasus: A comparative price transmission analysis*". This research contribution investigates the integration of Central Asian wheat markets in Kyrgyzstan, Tajikistan, and Uzbekistan and the South Caucasian wheat markets in Azerbaijan, Armenia, and Georgia with the wheat export markets in the Black Sea region (Russia, Ukraine, and Kazakhstan) and world markets (France and the USA). The price transmission analysis is complemented with the analysis of historical wheat price volatility in these markets.

Households in Central Asia and the South Caucasus spend a large portion of their income on food, as much as 49% on average in Armenia and 63% in Tajikistan, for example. Among all food items, wheat, mainly in the form of bread, accounts for a large share of total daily food calories, ranging from 40% to 60% in both regions. Since wheat is the primary source of calories in those countries, efficient functioning of grain markets is essential in terms of alleviating existing problems related to acute food insecurity in the regions.

Domestic wheat production in these regions does not suffice for local consumption and most of the wheat demand is covered by imports from the Black Sea region. Specifically, Russia, Kazakhstan, and Ukraine account for over 90% of total wheat imports to Central Asian and South Caucasian countries (Fig. 1.2.3). Furthermore, total transportation costs

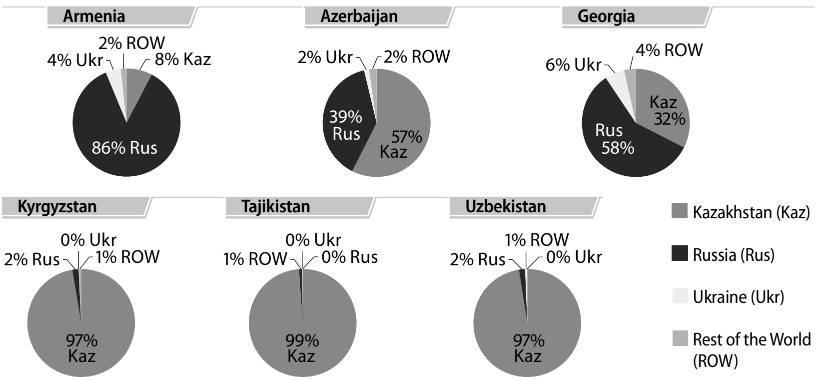

Fig. 1.2.3: Share of the Black Sea region in total wheat imports to Central Asia and the South Caucasus, 2006–2014

Source: UN Comtrade (2016)

of wheat are substantially higher in Central Asia compared to the South Caucasus due to the high informal payments. Pomfret (2016) points out that trade in Central Asia is not only characterized by high transportation costs, but also by inadequate regional trade infrastructure, resulting in slow movement of cargos and long delays at the border crossing points in this region.

The remainder of this thesis is structured as follows: In the following Chapters (2, 3 and 4), I present four research contributions, which are grouped into three categories. Chapter 2 combines research on the measurement and determinants of spatial market efficiency of the Russian grain markets and chapter 3 sheds light on the domestic price effects of export restrictions on the integration of the grain markets in Russia, while Chapter 4 presents research conducted on the wheat markets in Central Asia and the South Caucasus. Chapter 5 provides a discussion of the results and policy implications followed by a brief summary of thoughts on future research.

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2 MEASUREMENT AND DETERMINANTS OF SPATIAL MARKET EFFICIENCY OF GRAIN MARKETS IN RUSSIA AND GLOBAL FOOD SECURITY

2.1 SPATIAL MARKET EFFICIENCY OF GRAIN MARKETS IN RUSSIA AND GLOBAL FOOD SECURITY: A COMPARISON WITH THE USA

Earlier version of this article has won the Best Presentation award at the 57th Annual Conference of the German Society of Economic and Social Sciences in Agriculture (GeWiSoLa). Contribution: "How well is the Russian wheat market functioning? A comparison with the corn market in the USA", authors: M. Svanidze (presenter) and L. Götz.

Earlier versions of this paper were presented as:

- Contributed Paper at the 57th Annual Conference of the German Association of Agricultural Economists (GeWiSoLa) "Bridging the Gap between Resource Efficiency and Society's Expectations in the Agricultural and Food Economy", September 13–15, 2017, Munich, Germany.
- Contributed Paper at the XV EAAE Congress "Towards Sustainable Agri-Food Systems: Balancing between Markets and Society", August 29–September 1, 2017, Parma, Italy.
- Contributed Paper at the AAEA Annual Meeting, July 30–August 1, 2017, Chicago, USA.
- Contributed Paper at the IAMO Forum 2017 "Eurasian Food Economy between Globalization and Geopolitics", June 21–23, 2017, Halle (Saale), Germany.

Study outcomes also constitute a part of the World Bank report:

- World Bank (2018). Europe and Central Asia – The impacts of the El Niño and La Niña on large grain producing countries in ECA: yield, poverty and policy response. Washington, D.C.: World Bank Group.

Spatial market efficiency of grain markets in Russia and global food security: A comparison with the USA

Abstract

Using a threshold vector error correction model approach we find the wheat market of Russia segmented, with the primary grain export region poorly integrated into the domestic market. Results also indicate that trade costs are high, hindering spatial market efficiency of wheat markets in Russia. In addition, our study demonstrates that, by including the USA as benchmark country, a comparative approach enables a more comprehensive assessment of the spatial market efficiency of the wheat market in Russia. The study shows that the distinction between grain production and export potential, especially for markets located in peripheral regions of Russia, is essential to correctly identify Russia's future role for global food security. As a general conclusion, besides raising agricultural production potential it is also essential to strengthen spatial market efficiency in the agricultural sector to boost agricultural export potential and to increase global food security.

Keywords: spatial market efficiency, grain production potential, Russia, TVECM, regularized Bayesian estimator

1 Introduction

Grain production in Russia has shown an impressive growth since the dissolution of the Soviet Union in 1991. While Russia has previously been a large wheat importer, it had started to export wheat to the world market not until the beginning of the new century. Recently, Russia advanced to the largest wheat exporter in the world with wheat export amounting to 15% and 22% of global wheat export in 2016 and 2017, respectively (USDA-WASDE, 2017).

It is expected that Russia's role in international wheat export markets and thus global food security will further increase. Grain production in Russia could be further boosted by increasing grain production efficiency and also by re-cultivating formerly abandoned agricultural land (Bokusheva and Hockmann, 2006; Lioubimtseva and Henebry, 2012). Especially, Russia's additional grain production potential is assessed by Swinnen et al. (2017) to range between 25 and 65 million tons and by Deppermann et al. (2018) between 21 and 86 million tons.

However, the additional wheat production potential not only has to be mobilized but also has to be transformed into additional export potential to further increase Russia's importance for global wheat exports. This requires a spatially efficient domestic grain market, ensuring comprehensive and quick transmission of price changes from the grain export to the grain production regions.

In this study, we address the spatial market efficiency of the grain markets in Russia from a regional perspective. Following a price transmission approach, we focus on the primary grain production regions in Russia and measure their integration among each other. We investigate wheat price relationships between different grain production regions characterized by large distances and within selected grain production regions with relatively small distances.

The analysis is based on the assumption that in a spatially efficient market price shocks in one region are to a large degree and quickly transmitted to the other regions inducing interregional trade flows when price differences exceed trade costs (Fackler and Goodwin, 2001). Further, an efficient market is characterized by adequate trade costs, which are determined, for example, by the distance to other markets, quality and quantity of transport infrastructure, search costs and market risk (Tomek and Robinson, 2003).

We investigate the wheat market of Russia by contrast to the corn market of the USA. We assume that the corn market of the USA is one of the most efficient grain markets in the world and serves as an empirical benchmark (rather than a theory-based benchmark) for assessing the efficiency of the wheat market of Russia. Comparing the values of the estimated model parameters obtained for Russia vis-a-vis the USA, we measure the degree of spatial market efficiency of the Russian wheat market against the maximum degree of efficiency obtainable for grain markets in an empirical context. EU wheat market is also large to serve for comparisons, however, not yet uniform due to several rounds of rather recent enlargements with formerly centrally planned transition countries in 2004, 2007 and 2013 (Tocco et al., 2015).

Because corn is the primary feed grain in the USA, we choose corn market rather than the wheat market of the USA for comparisons. Corn is also mainly produced and consumed domestically and heavily traded within the USA, similar to wheat in Russia. Further, grain trade in both countries is characterized by large distances, which is decisively important for the analysis of spatial price relationships.

We measure market integration based on a threshold vector error correction model (TVECM) to explicitly account for the trade costs. We choose a novel Bayesian estimator suggested by Greb et al. (2013) which outperforms conventional maximum likelihood approach especially in small samples (Greb et al., 2014). However, this model framework with its bivariate setup is only allowing pairwise price analysis. We utilize a data set consisting of 40 price pairs for Russia and 106 price pairs for the USA.

This study adds to the existing body of literature in the following ways.

First, it contributes to the price transmission literature by measuring spatial integration of regional grain markets within Russia. Götz et al. (2016) have also investigated the integration of regional wheat markets of Russia, however, with respect to the world wheat market. Further, Serebrennikov and Götz (2015) confirm that regional wheat trade reversal during the export ban in 2010 caused a change in direction of price adjustment between markets as compared to the free trade regime. For the USA, several studies have investigated the integration of commodity markets at the interregional (Benirschka and Binkley, 1995; Brorsen et al., 1985; Goodwin and Schroeder, 1991) and intraregional level (Goodwin and Piggott, 2001; Schroeder, 1997). Goodwin and Piggott (2001) confirm strong market integration of the corn market in the USA. In contrast, Holst and von Cramon-Taubadel (2013) find stronger integration of EU pork markets within old or new member states, whereas market integration is weaker between old and new member states.

Second, our study adds to the strand of literature investigating the role of trade costs in agricultural market integration. For Russia, Renner et al. (2014) indicate that the volume of interregional grain trade decreases with increasing trade costs and less developed transport infrastructure. Trade costs also influence spatial market integration, as found by Moser et al. (2009) for rice markets in Madagascar. Furthermore, Jamora and von Cramon-Taubadel (2016) demonstrate that rice prices in 47 importing countries adjust at a lower speed with increasing distance to the international rice markets.

Third, our study contributes to the literature assessing Russia's role for future global food security. Most studies on Russia's additional grain production potential (for an overview see Schierhorn et al., 2014 and Swinnen et al., 2017) have focused on estimating Russia's capacity to increase its grain production via improvements in grain yields, expansion of agricultural land or changes in climatic conditions. This paper adds to this literature by focusing on the importance of spatially efficient markets for transforming Russia's grain production potential into grain export potential.

The remainder of this article is organized as follows. Russia's wheat market characteristics are discussed and compared to the corn market of the USA in section 2, whereas section 3 addresses the methodological framework and model estimation. Section 4 discusses the data specifications and section 5 presents empirical results. Finally, we discuss results and draw conclusions in section 6.

2 Characteristics of the grain market in Russia and its comparison with the USA

We follow a comparative approach and investigate the wheat market in Russia by contrast with the corn market of the USA.

Whereas wheat is the primary grain produced in Russia constituting 60% of grain production, corn represents 80% of total grain production in the USA (USDA-WASDE, 2016). Contrasting, the share of wheat in total grain production in the USA is only 15% with further decreasing tendency.

Grain production in Russia, as in the USA, is concentrated on a limited, yet spatially protracted area. Six economic regions supply nearly all wheat produced in Russia (Fig. 2.1.1). North Caucasus, Black Earth, Volga, Ural and West Siberia are wheat surplus regions, whereas Central region with Moscow is the primary wheat deficit region, which largely depends on external supplies.

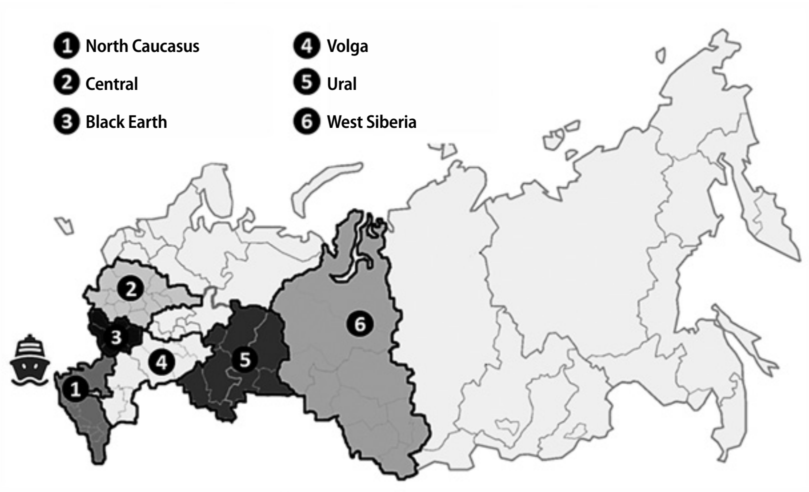


Fig. 2.1.1: Map of grain producing economic regions of Russia

Source: Own elaboration

The concentration of human grain consumption in few city centers (Moscow, St. Petersburg) and livestock producing regions (Central and Black Earth) in Russia requires that a large amount of wheat is transported from production to consumption sites over large distances. Contrasting, ethanol plants and livestock farms in the USA are concentrated in the main corn production regions, ensuring that corn is primarily transported over small distances. Only a few large corn net-consuming states of the USA, such as California, Texas and Washington, heavily depend on grain transported from other production regions. Washington is the grain export gateway to Asia, whereas Texas and California are among the largest livestock producing regions in the USA.

Wheat production in Russia is strongly influenced by climatic and weather conditions. Owing to vast distances, favorable production conditions and thus relatively high yields might be observed in some regions but relatively low yields in others at the same time. The variation of wheat production within a region is also generally high (Götz et al., 2016). In the Volga region, for example, average wheat production varied between 34% and 134% in 2009 to 2015. Large regional fluctuations also characterize corn production in the USA. In Illinois, for example, yearly corn production varied between 65% and 132%.

In Russia, North Caucasus is the primary production region, which almost exclusively supplies wheat to the world market, while its role in the domestic trade is rather limited. With its high-capacity sea terminals, North Caucasus also serves as a gate-market for the other grain producing regions, particularly Volga and Black Earth, to export to the world market. In contrast, Ural and West Siberia are far away not only from the world market, with the distance to the Black Sea ports amounting to 4000 kilometers, but also the grain consumption regions within Russia. In particular, Moscow is about 2000–3000 kilometer apart. Even the grain exports by Ural and West Siberia to the world market during the 2017/18 marketing season were heavily relying on large transport subsidies provided by the Russian government (USDA-GAIN, 2018).

Similarly, corn is transported over large distances between 1000 to 3000 kilometers in the USA especially from "Corn Belt" area states to

California and Texas for livestock production and Washington seaports for further export.

Transport infrastructure is outdated and insufficient in some regions and strongly differs between regions in Russia. For instance, the density of the railway network is highest in the European part of Russia, whereas it is much lower in Ural and West Siberia. Excessive crops are often difficult to transport beyond West Siberia as the only railway track connecting the area to the rest of the country has low throughput capacity and is shared by many other industries (Scherbanin, 2012). In addition, grain traders regularly complain that the number of grain wagons in peak seasons does not suffice (Agroinvestor, 2011).

Rail and road transports are the primary means of wheat transportation in Russia. Rail transport dominates if the transportation distance exceeds 1000 kilometer, while road transport is preferred for routes up to 500 kilometers. River transportation is quite unusual for grain deliveries in Russia. In contrast, river barge transport is common practice for grain transport over long distances in the USA due to the large weight capacity of barges and low costs (Fig. 2.1.2).

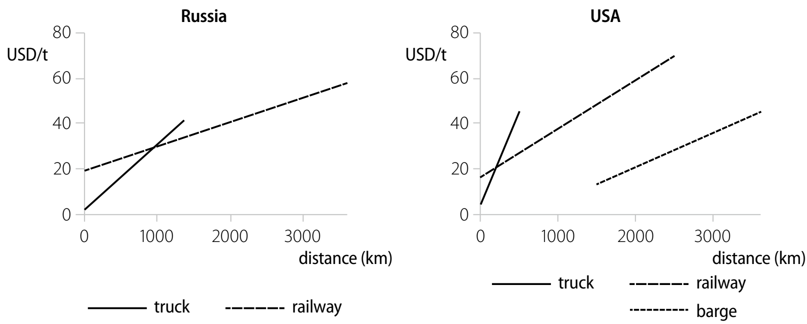


Fig. 2.1.2: Grain transportation tariffs in Russia and the USA

Note: We linearly approximate transportation tariffs based on actual rates given for different distance routes in 2010.

Source: AEGIC (2016), Rosstat (2015), US Rail Waybill Samples (2017) and USDA-AMS (2017)

Considering land transport, grain transportation tariffs are lower in Russia compared to the USA (Fig. 2.1.2). Nonetheless, overall transport costs are higher in Russia due to inadequate transport infrastructure and logistics, negatively influencing regional wheat trade volumes within Russia (Renner et al., 2014). In addition to high transport costs, grain markets in Russia are also characterized by high business and market risk (PWC, 2015). Especially, trade costs are high due to the difficulty to enforce contracts and unforeseen policy interventions on grain markets (Götz et al., 2016).

3 Methodological framework and model estimation

Market integration between two geographically separated regions can be analyzed based on the Law of One Price (LOP). LOP implies the same price for a homogeneous good in different locations once the differences in currency units and trade costs are accounted for. Market integration is achieved via efficient commodity arbitrage, which ensures price information is transmitted between markets, eventually resulting in the long-run price parity (Ardeni, 1989).

Therefore, a spatially efficient market is an integrated market characterized by a complete transmission of price changes between markets in the long run. However, short-run transitory inefficiencies that are quickly eliminated via profitable arbitrage are allowed in a spatially efficient market. Further, spatial market efficiency could be enhanced by decreasing trade costs.

Prices in spatially separated markets in region 1 and region 2 linked by a spatial price equilibrium are represented by

$$p_{1t} = \alpha + \beta p_{2t} + \varepsilon_t \quad (1)$$

where p_{1t} and p_{2t} are domestic prices (in natural logarithm) observed in regional markets 1 and 2, α denotes the intercept and β is the coefficient of the long-run price transmission elasticity, characterizing the magnitude of transmission of price shocks from one market to another. The theoretical value of β varies between zero and one, with $\beta = 1$ indicating that price information is completely transmitted in perfectly integrated markets. ε_t represents the stationary disturbance term, which might not be white noise. Equation (1) is built on an implicit assumption that trade costs are stationary ensuring that the long-run price equilibrium can be correctly identified (Fackler and Goodwin, 2001).

The concept of a long-run equilibrium is a static notion. It is natural that prices in spatially separate markets often diverge from this parity owing to unexpected market shocks. Dynamic linear and threshold vector error correction models (VECM and TVECM) offer to measure the speed at which prices converge back to the long-run equilibrium as a result of profitable arbitrage activities by agricultural traders.

If the price series are linearly cointegrated, then a linear vector error correction model developed by Johansen (1988) enables quantifying the short-run price dynamics as

$$\Delta \boldsymbol{p_t} = \boldsymbol{\rho}\varepsilon_{t-1} + \sum_{m=1}^{M} \boldsymbol{\Theta}_m \Delta \boldsymbol{p}_{t-m} + \boldsymbol{\omega}_t \tag{2}$$

where the vector of dependent variables $\Delta \boldsymbol{p}_t = (\Delta p_{1t}, \Delta p_{2t})$ denotes difference between the prices in periods t and $t-1$ for markets 1 and 2. The error correction term ε_{t-1}, i.e. the lagged residuals retrieved from equation (1), represents the price deviation from the long-run price equilibrium. The short-run dynamics of prices p_{1t} and p_{2t} are characterized by the speed of adjustment parameter $\boldsymbol{\rho} = (\rho_1, \rho_2)$, with the expected value of $\rho_1 \leq 0$ and $\rho_2 \geq 0$, which measures how quickly deviations from the long-run equilibrium are eliminated. In order to ensure a smooth convergence to equilibrium, total speed of adjustment should range between zero and one achieved by satisfying the condition $0 < \rho_2 - \rho_1 < 1$ (Greb et al., 2014). $\boldsymbol{\Theta}_m = (\Theta_{1m}, \Theta_{2m})$ indicates the lagged influence of the price changes $\Delta \boldsymbol{p}_{t-m}$ with lags $m = 1, \ldots, M$, ensuring that the model residuals are serially uncorrelated. $\boldsymbol{\omega}_t = (\omega_{1t}, \omega_{2t})$ denotes a white noise process with expected value $E(\boldsymbol{\omega}_t) = \mathbf{0}$ and covariance matrix $Cov(\boldsymbol{\omega}_t) = \boldsymbol{\Omega} \in (\mathbb{R}^+)^{2\times 2}$.

In practice, however, trade costs often determine the intensity of spatial trade arbitrage, such that price deviations larger than the trade costs are more quickly eliminated compared to smaller price deviations. Thus, a "regime dependent" price adjustment process may be observed, which can be depicted by a threshold error correction model where the threshold corresponds to the size of transaction costs.

A non-linear three-regime TVECM with two thresholds (Greb et al., 2013) makes it possible to account for the influence of trade costs, which are due to large distances highly relevant to trade in the Russian wheat market:

$$\Delta \boldsymbol{p_t} = \begin{cases} \boldsymbol{\rho}_1 \varepsilon_{t-1} + \sum_{m=1}^{M} \boldsymbol{\Theta}_{1m} \Delta \boldsymbol{p}_{t-m} + \boldsymbol{\omega}_{1t}, & if \quad \varepsilon_{t-1} \leq \tau_1 \\ \boldsymbol{\rho}_2 \varepsilon_{t-1} + \sum_{m=1}^{M} \boldsymbol{\Theta}_{2m} \Delta \boldsymbol{p}_{t-m} + \boldsymbol{\omega}_{2t}, & if \quad \tau_1 < \varepsilon_{t-1} \leq \tau_2 \\ \boldsymbol{\rho}_3 \varepsilon_{t-1} + \sum_{m=1}^{M} \boldsymbol{\Theta}_{3m} \Delta \boldsymbol{p}_{t-m} + \boldsymbol{\omega}_{3t}, & if \quad \tau_2 < \varepsilon_{t-1} \end{cases} \tag{3}$$

The speed of adjustment parameter is constant in a linear VECM, whereas it may differ between the regimes r, $r = \{1,2,3\}$ in a non-linear TVECM. The speed of adjustment is usually higher in the lower ($r = 1$) and upper ($r = 3$) regimes compared to the middle ($r = 2$) regime due to trade arbitrage. However, profitable arbitrage opportunities do not exist in the middle regime, as trade costs exceed price deviations. Nonetheless, the price adjustment may be observed in this regime due to information flows or third markets (Stephens et al., 2012).

The error correction term ε_{t-1} also serves as a threshold variable τ in TVECM. The three-regime TVECM assumes that two thresholds (τ_1 and τ_2) exist corresponding to the size of trade costs in both directions, i.e. from one market to the other and vice versa. Trade reversal is captured by the restriction $\tau_1 < 0 < \tau_2$. The model further assumes that trade costs are a constant fraction of prices as the model variables are transformed into a natural logarithm. The size of trade costs is also captured by the band of inaction, defined as the difference between the absolute value of the upper and lower threshold. Thus, a large band of inaction indicates that trade costs are substantial.

In a TVECM, the threshold variable τ determines the state of the regime r, $r=\{1,2,3\}$ depending on the size of the error correction term relative to the size of the thresholds. To identify optimal thresholds, we apply the novel regularized Bayesian estimator (Greb et al., 2014) as an alternative to the classical maximum likelihood (Hansen and Seo, 2002) and the least squares (Chan, 1993) estimator. Different to the traditional estimators, which use the grid search procedure to identify the optimal threshold values, the regularized Bayesian estimator uses informative priors to achieve the desired distribution of observations across regimes, which is well defined on the entire space of threshold parameters. Furthermore, the regularized Bayesian estimator outperforms maximum likelihood and non-informative Bayesian estimators, especially in small samples (Greb et al., 2014).

According to Greb et al. (2013), integral calculus might be more natural to use in TVECM as it provides a means to tackle the inherent variability of the estimates. The posterior median, which is used to choose the optimal threshold values, is constructed as

$$\int_{\min(\varepsilon_{t-1})}^{\hat{\tau}_{irB}} P_{rB}\left(\tau_i|\Delta\boldsymbol{p},\boldsymbol{X}\right)d\tau_i = 0.5, \mathit{for}\, i = 1,2 \tag{4}$$

where $\boldsymbol{X}$ is an $n \times d$ matrix that compactly stacks the columns of error correction terms together and values of lagged terms. $P_{rB}\left(\tau_i|\Delta\boldsymbol{p},\boldsymbol{X}\right)$ is well defined across the space of all possible threshold parameters $\mathrm{T} = \{(\tau_i)|\min(\varepsilon_{t-1}) < \tau_i < \max(\varepsilon_{t-1})\}$. Computation of τ is based on a prior $P_{rB}\left(\tau|\boldsymbol{X}\right) \propto I\left(\tau \in T\right)$ which is independent of regime-specific parameters, where $I(\cdot)$ is an indicator function providing switching between regimes. Upon identification of the optimal thresholds, we estimate the additional parameters of the TVECM. We use the restricted maximum likelihood framework implemented as part of the mixed-effects modelling in R (Gałecki and Burzykowski, 2013).

In the price transmission analysis, we proceed as follows. Given that price series are identified as integrated of order one (Dickey and Fuller, 1981), we proceed to test if the price pairs of interest are linear or threshold cointegrated and thus if a long-run price equilibrium exists. We examine the existence of linear cointegration based on Johansen (1988) test. Threshold cointegration is tested within the Hansen and Seo (2002) framework in a two-regime TVECM with one threshold. Additionally, we use the Larsen (2012) extension to the Hansen and Seo (2002) test by allowing for non-linear cointegration within a three-regime TVECM with two thresholds. Given that linear or threshold cointegration is confirmed we estimate a VECM or a TVECM, respectively.

4 Data

The interregional analysis centers on price relationships between different grain production regions separated by large distances. Contrasting, price relationships within one individual grain production region with small distances between markets are in the focus of the intraregional analysis (Table 2.1.1).

Table 2.1.1: Database of grain price series underlying price transmission analysis

Country	Marketing Year	Price Pairs	Data frequency	Data source
Interregional analysis (between regions/federal states)				
Russia (6 regions)	2009–10	15	Weekly	Rus. Gr. Union (2014)
USA (16 federal states)		63		USDA-AMS (2016)
Intraregional analysis (within regions/federal states)				
Black Earth (region)	2014–16	10	Biweekly	Min. of Ag. (2016)
West Siberia (region)		15		
Iowa (federal state)		28	Weekly	GeoGrain (2016)
North Carolina (federal state)		15		

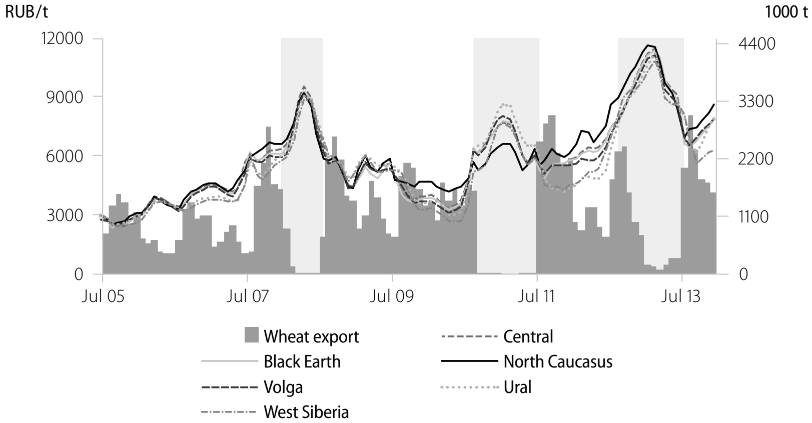


Fig. 2.1.3: Development of regional wheat prices in Russia during 2005–2013

Note: The bold area on the graph represents the periods of export tax (Nov 2007–May 2008), export ban (Aug 2010–Jul 2011) and draught season (2012–2013). Source: Russian Grain Union (2014), GTIS (2013)

For the interregional analysis of the grain market of Russia, we make use of a unique data set of weekly prices of wheat of class three (Ruble/ton). This data is collected by the Russian Grain Union and is not publicly available. Our data set comprises regional price series for the six primary grain production regions North Caucasus, Black Earth, Central, Volga, Ural and West Siberia during 2005–2013 (Fig. 2.1.3).

However, the regional price relationships in Russia are not stable, but rather differ from marketing year to marketing year. Due to the common harvest shortfalls in Russia and thus the large variation in regional grain production, the size and direction of trade flows between surplus and deficit regions vary strongly (Götz et al., 2016).

In particular, the price in North Caucasus is in some years higher and in other years lower than prices in, for example, Volga and West Siberia regions (Fig. 2.1.4). Oscillating behavior of prices coincides with the change in the direction and size of interregional trade flows resulting from large variations in the regional grain harvest due to weather conditions.

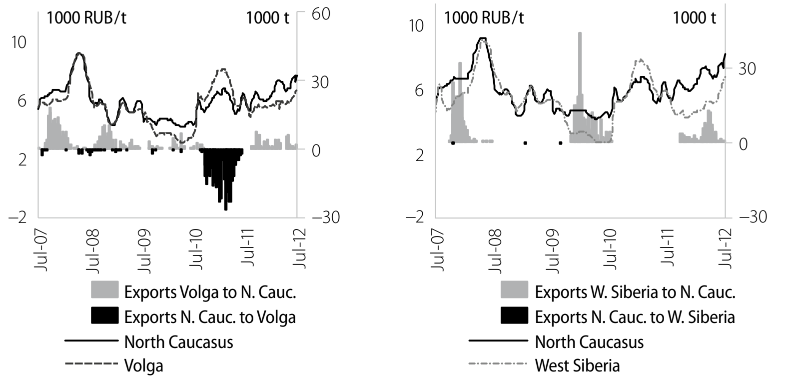


Fig. 2.1.4: Wheat prices and regional trade: North Caucasus and Volga (left), North Caucasus and West Siberia (right)

Source: Reproduced from Götz et al. (2016)

This implies that the interregional price relationships, which are depicted in the price transmission model, are not stable, and thus parameter estimates may not be constant. We suspect that the data generating process differs from one marketing year to another. This requires the price transmission model for Russia to be estimated based on one marketing year only, which is characterized by relatively stable price relationships.

Therefore, to assess the strength of market integration in Russia at the interregional level, we confine our analysis to the price data of the individual grain production regions of the marketing year 2009–10 only, in which trade was freely possible. We construct altogether 15 price pairs comprising 52 weekly observations for each price series.

Correspondingly, we employ weekly corn prices for 16 federal states of the USA of 52 observations for the marketing year 2009–10 (USDA-AMS, 2016). We generate 63 price pairs, by combining prices observed in seven "Corn Belt" area states with prices monitored in nine corn net-consuming states.

For the intraregional integration of the grain market of Russia, we use prices observed within the two primary wheat producing regions Black

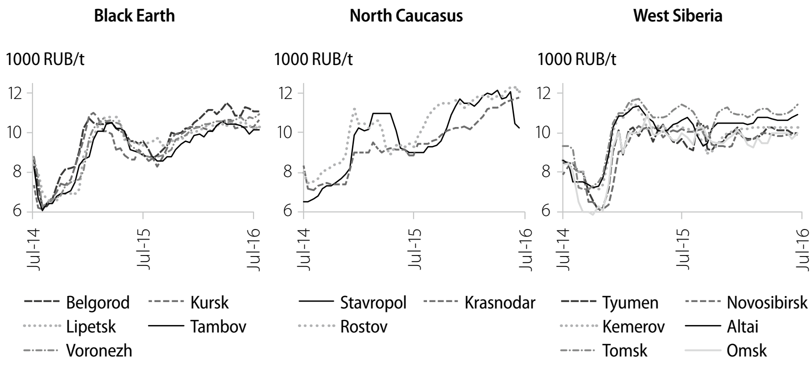


Fig. 2.1.5: Development of regional wheat prices in Black Earth, North Caucasus and West Siberia during 2014–2016

Source: Ministry of Agriculture (2016)

Earth and West Siberia (Ministry of Agriculture, 2016; Fig. 2.1.5). Since price series for Russia are only available at the biweekly frequency, we increase the sample size to two years to ensure a relatively sufficient number of observations for the price transmission analysis. Thus, we utilize 10 price pairs for Black Earth and 15 price pairs for West Siberia, each price series comprising 52 biweekly observations in the period July 2014 to August 2016.

We choose West Siberia as it is one of the largest grain production regions in Russia, primarily involved in domestic wheat trade due to its large distances to the world market. However, instead of Black Earth, we would have preferred to analyze price relationships in North Caucasus, which is the primary grain export region with direct access to its ports at the Black Sea. Nonetheless, since the quality of the price data for North Caucasus (Fig. 2.1.5) does not suffice the data requirements for a rather complex TVECM we choose its neighboring Black Earth region as an alternative.

Likewise, the intraregional analysis for the USA covers Iowa, leading corn production and export region, and North Carolina, which similarly to West Siberia in Russia, mainly supplies its excess corn production to the domestic market. The price series for Iowa and North Carolina are supplied by the consultancy company GeoGrain (2016). Thus, we analyze 28 price pairs for Iowa and 15 price pairs for North Carolina, each price series comprising 110 weekly observations (July 2014 to August 2016).

5 Empirical results

5.1 Data properties

Results of the Augmented Dickey-Fuller test (Dickey and Fuller, 1981) suggest that all price series included in the interregional and the intraregional analysis are integrated of order one (Table A.2.1.1, Appendix).

The tests on cointegration of the price pairs involved in the interregional analysis indicate that linear or threshold cointegration is identified for all 15 price pairs representing the Russian wheat market, and 53 out of 63 price pairs for the corn market in the USA, whereas at the intraregional level cointegration is confirmed for all price pairs for Russia and 40 out of 43 price pairs for the USA (Table 2.1.2). Therefore, we exclude the 13 price pairs (out of 106) for the corn market of the USA, for which neither linear nor threshold cointegration is confirmed, from the analysis.

Table 2.1.2: Summary results of cointegration tests

Number of …	Russia	USA
interregional price pairs (between regions/federal states)	**15 (total)**	**63 (total)**
Threshold cointegrated	15	35
Linear cointegrated	13	48
Linear or threshold cointegrated	15	53
intraregional price pairs (within regions/federal states)	**25 (total)**	**43 (total)**
Threshold cointegrated	21	32
Linear cointegrated	25	25
Linear or threshold cointegrated	25	40

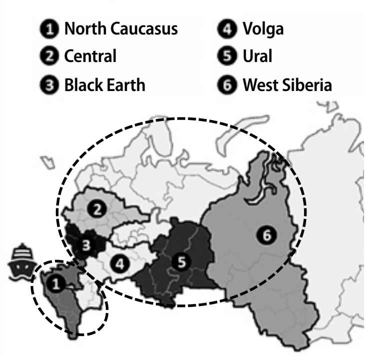
Note: Estimated parameters are given in Tables A.2.1.2 and A.2.1.3 in Appendix.

5.2 Measurement of market integration

In this subsection, we present selected estimation results of the wheat price transmission analysis for Russia and the comparison with the corn market of the USA. Specifically, we focus on the long-run price equilibrium, the correction of temporary disequilibrium and the estimates of trade costs.

Table 2.1.3: Long-run price transmission elasticities: Russia, interregional analysis

Price pair	Distance (km)	Long-run price transmission elasticity (β)
Central–Black Earth	526	0.94
Central–Volga	801	0.70
N. Caucasus–Black Earth	**870**	**0.33**
Black Earth–Volga	1035	0.74
Volga–Ural	1235	0.68
N. Caucasus–Central	**1300**	**0.35**
Ural–W. Siberia	1310	0.83
N. Caucasus–Volga	**1708**	**0.27**
Black Earth–Ural	2027	0.47
Central–Ural	2044	0.43
Volga–W. Siberia	2537	0.57
N. Caucasus–Ural	**2682**	**0.16**
Black Earth–W. Siberia	3329	0.39
Central–W. Siberia	3346	0.36
N. Caucasus–W. Siberia	**3984**	**0.13**



Note: Price pairs are sorted based on the distance between markets in an ascending order. Price pairs consisting of price for North Caucasus is shown in bold.

5.2.1 Long-run price equilibrium

Table 2.1.3 presents the long-run price transmission elasticities of the regional wheat prices in Russia (interregional analysis).

It becomes evident that the long-run price transmission elasticity decreases with increasing distance between the regions. Corresponding with the Law of One Price, according to which markets are perfectly integrated if the slope parameter of the long-run price equilibrium is equal to one, the integration of wheat markets between regions of Russia is weaker, the higher the distance between those regions.

In particular, long-run price transmission is the strongest between the neighboring regions Central and Black Earth (0.940), with Central as the major consumption center and Black Earth as a large production region, and the lowest between North Caucasus and West Siberia (0.132), the two grain producing regions, which are the most apart.

Further, results indicate that North Caucasus is the least integrated with the other grain producing regions of Russia. Price changes are transmitted between markets by 13% to 35% if one of the two regions in question is North Caucasus, whereas prices are transmitted by 36% to 94% between other regions of Russia. Obviously, the export region negatively affects the degree of wheat market integration in Russia.

The previously discussed long-run price transmission elasticities of the 15 price pairs for Russia at the interregional level are presented together with the long-run price transmission elasticities of the 53 price pairs for the USA as boxplots in Fig. 2.1.6 (left). The long-run price transmission parameters estimated within the intraregional analysis for Russia and the USA are shown in Fig. 2.1.6 (right).

When assessing the price transmission elasticities obtained for the corn market of the USA against the theory-based benchmark, the results indicate that corn prices are very strongly related as price transmission elasticities (0.86, 0.97 and 0.95) nearly equal to one.

Concerning cross-country comparisons, median long-run price transmission elasticity equals to 0.43 for Russia and 0.86 for the USA at the interregional level. Thus, price changes between spatially separated markets are transmitted by twice as much in the USA compared to Russia.

Results of the intraregional analysis indicate that median long-run price transmission elasticities equal to 0.97 and 0.95 for Iowa and North Carolina in the USA and 0.94 and 0.81 for Black Earth and West Siberia in Russia, respectively.

Thus, the differences in the long-run price transmission elasticities between Russia and the USA is much larger at the interregional level than at the intraregional level.

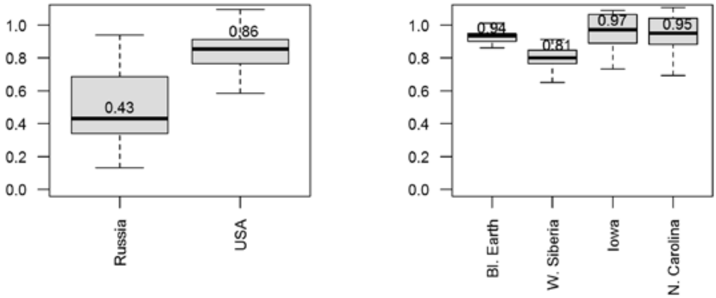


Fig. 2.1.6: Boxplots of the estimated long-run price transmission elasticity parameters: interregional analysis (left), intraregional analysis (right)

Note: Plots are based on estimated parameters given in Table 2.1.3 and Tables A.2.1.4 and A.2.1.5 in Appendix.

5.2.2 Correction of the temporary disequilibrium

Estimated price adjustment parameters for Russia are directly compared to the USA within the boxplots in Fig. 2.1.7.

The estimated adjustment parameters (at the bi-weekly frequency) suggest that the price disequilibrium is eliminated at a rate of 0.8 in the corn market of the USA, whereas the theoretical value would be one in a spatially efficient market. This difference between the theoretical and empirical values is even more pronounced at the intraregional level indicating that empirical benchmark at the intraregional level is 0.6, which is by 40% lower compared to the theoretically obtainable speed of price adjustment parameter.

Results indicate that the median speed of adjustment is by nearly 40% lower for Russia (0.42) compared to the USA (0.81) at the interregional level (Fig. 2.1.7, left).

Results at the intraregional level demonstrate that about 60% of the temporary price disequilibrium is eliminated in two weeks within Iowa

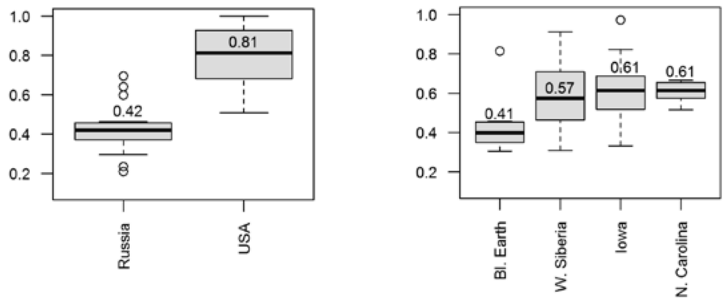


Fig. 2.1.7: Boxplots of the estimated speed of adjustment parameters: interregional analysis (left), intraregional analysis (right)

Note: Plots are based on estimated parameters given in Tables A.2.1.6 and A.2.1.7 in Appendix. To compare the speed of adjustment parameters of different frequencies we convert parameters from weekly to biweekly frequency by using following formula $|\rho|^{\text{biweekly}} = 1-(1-|\rho|^{\text{weekly}})^2$.

(0.61) and North Carolina (0.61), whereas price adjustment is by 30% and 5% lower in Black Earth (0.41) and West Siberia (0.57), respectively (Fig. 2.1.7, right). This suggests that at the intraregional level, spatial market efficiency of the wheat market in Russia is comparable to that of the corn market of the USA. If evaluated against the theoretical benchmark, one might conclude that the speed of adjustment of wheat prices in the Russian market is low with the speed of price adjustment parameter amounting to only 50% of the theoretical benchmark value of 1.

Thus, the speed of adjustment in Russia is significantly lower compared to the USA at the interregional level, while differences are much smaller at the intraregional level.

5.2.3 Trade costs

We directly compare the estimated parameters of the band of inaction for Russia and the USA within the boxplots in Fig. 2.1.8.

Estimates of the threshold parameters for Russia generally confirm the influence of distance. Values of the band of inaction are lowest

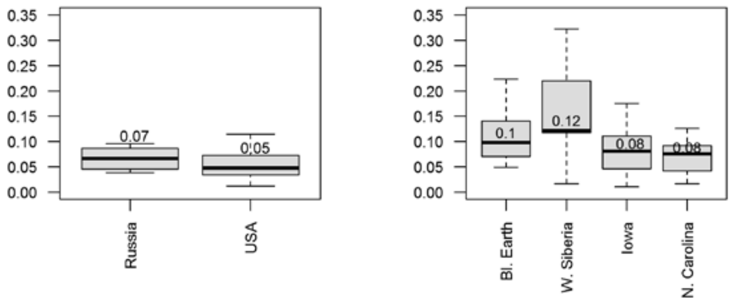


Fig. 2.1.8: Boxplots of the estimated band of inaction parameters: interregional analysis (left), intraregional analysis (right)

Note: Plots are based on estimated parameters given in Tables A.2.1.6 and A.2.1.7 in Appendix.

between neighboring regions and largest between regions the furthest apart. Especially, all price pairs including Ural or West Siberia as a region are characterized by a relatively large band of inaction values in the range of 0.07 and 0.10 compared to other market pairs with the band of inaction varying between 0.04 and 0.06. This implies that the cost of interregional trade is particularly high for Ural and West Siberia.

Since the size of trade costs in a spatially efficient market is not defined in the literature, estimating thresholds for the corn market of the USA allows evaluating the magnitude of trade costs for the Russian wheat market against the size of trade costs identified for the corn market of the USA. The comparison of the size of the estimated band of inaction for Russia and the USA at the interregional level makes evident that the median band of inaction is by 40% higher for Russia compared to the USA (Fig. 2.1.8, left). Results at the intraregional level suggest that the band of inaction for Black Earth and West Siberia is by 25% and 50% higher compared to the USA (Fig. 2.1.8, right).

6 Discussion of results and conclusions

This study has made evident that the integration of regional grain markets mostly in distant grain producing regions within Russia is relatively low compared to the USA. However, differences in spatial market efficiency within grain production regions in Russia and the USA, where grain is traded over short distances, are much smaller.

Further, our study has demonstrated that differences exist between the empirically obtained benchmark estimates and theory-based values, especially regarding the speed at which temporary deviations from the equilibrium are corrected and the size of trade costs. Thus, the comparative approach has enabled a more comprehensive assessment of the spatial market efficiency of the wheat market of Russia.

The analysis of the interregional price transmission in Russia has made evident that the Russian wheat market is not uniformly integrated but rather subdivided into two clusters. Especially, the grain production region in the North Caucasus, which primarily exports grain to the world market, is only poorly integrated with the other five large grain production regions, which are mainly involved in domestic grain trade within Russia. This implies that price developments in North Caucasus, which are strongly co-moving with prices on the world market (compare Götz et al., 2016), are only to a limited extent transmitted further to grain production regions of Russia. Also, results indicate that trade costs in Russia are high. Especially, trade costs are the highest for the distant grain markets in Ural and West Siberia, explaining their extremely weak integration with the export market in North Caucasus.

This has meaningful implications for West Siberia and Ural, which bear large additional grain production potential, accounting for between 25% to 35% of Russia's additional grain production potential of 25 to 65 million tons (Swinnen et al., 2017). However, under current market conditions with a weakly integrated wheat market and high trade costs, the additional wheat production potential in Ural and West Siberia cannot be transformed into additional export potential. Thus, taking these two additional factors into account, Russia's additional grain export potential could increase by at most 15–45 million tons (for calculations see Table A.2.1.8, Appendix). Further, our results imply that Russia's additional grain export potential falls below the estimated 70 million tons by Deppermann et al. (2018), which assumes that 90% of the additional grain production is transformed into additional grain export.

The mobilization of grain export potential in grain production regions will require substantial investments in the grain market and transportation infrastructure to improve their integration in the export market. The enhancement of the efficiency of Russia's wheat market would ensure the faster transmission of price signals between regions inducing concomitant flows of trade from surplus to deficit regions. This would contribute to cushioning the price increasing effects of regional harvest shortfalls, which are expected to become more widespread with climate change (Coumou and Rahmstorf, 2012). Strengthened domestic wheat price stability would reduce incentives for the government to implement export controls on the wheat market as a crisis policy, which induce welfare losses to farmers and traders and negatively affect the further development of the grain sector, and especially the development of the commodity futures markets.

Further, a spatially efficient wheat market in Russia would ensure that the additional wheat production potential is transformed into additional export potential, strengthening Russia's importance in future global wheat export markets and thus, for global food security by becoming a breadbasket of the world.

In general, this study has made evident the importance to distinguish between agricultural production potential and agricultural export potential, especially if production potential is located in regions, which are distant to the world markets. Since several large-scale countries beyond Russia are attributed high importance for future global food security (e.g. Brazil), spatial market efficiency should be given more attention as a further factor determining a country's role for future global food security. Therefore, we suggest that a spatial market efficiency should be included in global scenario studies (for an overview see Le Mouël and Forslund, 2017) to assess future global food security.

Also, this study has shown that to foster global food security, it is not sufficient to focus on raising agricultural production potential e.g. by technological progress in plant breeding and agronomic practices, but also to explicitly boost agricultural export potential by enhancing spatial market efficiency in the agricultural sector.

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APPENDIX

Table A.2.1.1: Augmented Dickey-Fuller test for prices in levels and first differences

Price series	Determ. Component	Lags	Test-stat.	Δ price series	Determ. Compo-nent	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***
Ural	Constant	1	−2.170	Δ Ural	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***

(continued)

Table A.2.1.1 *(continued)*

Price series	Determ. Component	Lags	Test-stat.	Δ price series	Determ. Compo-nent	Lags	Test-stat.
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^{***}
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 A.2.1.2: Tests of cointegration: interregional analysis

Price pair	Hansen and Seo test (2002)[†, a]		Larsen test (2012)[†, b]	Johansen test (1988)[c]	
	Sup-Wald Test 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 – Ural	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 – Ural	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*	25.088	0.04	20.484** / 4.454	0.047 / 0.349
Black Earth – Ural	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 – Ural	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
Ural – 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
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

(continued)

Table A.2.1.2 *(continued)*

Price pair	Hansen and Seo test (2002) †, a		Larsen test (2012) †, b	Johansen test (1988) c	
	Sup-Wald Test statistic	5% cr. Value	P-value	Trace test statistic	P-value
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
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 A.2.1.3: Tests of cointegration: intraregional analysis

Price pair	Hansen and Seo test (2002)†, a		Larsen test (2012)†, b	Johansen test (1988) c	
	Sup-Wald Test 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 A.2.1.3 *(continued)*

Price pair	Hansen and Seo test (2002)[†, a]		Larsen test (2012)[†, b]	Johansen test (1988)[c]	
	Sup-Wald Test 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 A.2.1.4: Parameters of long-run price equilibrium: USA, interregional analysis

Price pair	Distance (km)	Long-run price Transmission elasticities (β)	Intercept Parameter (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
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 A.2.1.5: Parameters of long-run price equilibrium regression: intraregional analysis

Price pair	Distance (km)	Long-run price Transmission elasticities (β)	Intercept Parameter (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
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 A.2.1.6: Results of TVECM and VECM: interregional analysis

Price pair	Lower regime		Middle regime / VECM parameters[a]			Upper regime			Total adjustment[b]			
	Sp. Adj. $(\rho_1)^{\dagger}$	P-value	Thresh-old (τ_1)	Sp. Adj. $(\rho_2)^{\dagger}$	P-value	Thresh-old (τ_2)	Sp. Adj. $(\rho_3)^{\dagger}$	P-value	Lower	Middle	Upper	Band of Inaction[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 –Ural	−0.057	0.757	*−0.047*	−0.276	0.259	*0.029*	−0.316**	0.030	0.524	-	0.316	*0.076*
Ural – 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 – Ural	-	-	-	0.045	0.774	-	-	-	-	0.464	-	-
Ural – 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 – Ural	0.122	0.318	*–0.059*	0.122	0.318	*0.031*	0.010	0.928	0.503	0.503	0.349	*0.090*
Ural – 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 – Ural	–0.294	0.203	*–0.058*	–0.038	0.858	*0.038*	–0.506**	0.014	0.376	0.360	0.506	*0.096*
Ural – Volga	0.376*	0.067		0.360**	0.043		0.226	0.245				
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				
Ural – W. Siberia	–0.370*	0.072	*–0.027*	–0.337	0.183	*0.012*	–0.370	0.141	0.370	-	-	0.039
W. Siberia – Ural	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				

(continued)

Table A.2.1.6 *(continued)*

Price pair	Lower regime		Middle regime / VECM parameters [a]			Upper regime			Total adjustment [b]			
	Sp. Adj. $(\rho_1)^\dagger$	P-value	Thresh-old (τ_1)	Sp. Adj. $(\rho_2)^\dagger$	P-value	Thresh-old (τ_2)	Sp. Adj. $(\rho_3)^\dagger$	P-value	Lower	Middle	Upper	Band of Inaction [c]
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				

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*

(continued)

Table A.2.1.6 *(continued)*

Price pair	Lower regime		Middle regime / VECM parameters [a]			Upper regime			Total adjustment [b]			
	Sp. Adj. $(\rho_1)^\dagger$	P-value	Thresh-old (τ_1)	Sp. Adj. $(\rho_2)^\dagger$	P-value	Thresh-old (τ_2)	Sp. Adj. $(\rho_3)^\dagger$	P-value	Lower	Middle	Upper	Band of Inaction [c]
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				
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		-	-				
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				

(continued)

Table A.2.1.6 *(continued)*

Price pair	Lower regime		Middle regime / VECM parameters[a]			Upper regime			Total adjustment[b]			
	Sp. Adj. $(\rho_1)^{\dagger}$	P-value	Thresh-old (τ_1)	Sp. Adj. $(\rho_2)^{\dagger}$	P-value	Thresh-old (τ_2)	Sp. Adj. $(\rho_3)^{\dagger}$	P-value	Lower	Middle	Upper	Band of Inaction[c]
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	0.900			
Washington – Missouri	0.063	0.918	*−0.035*	0.081	0.896	*0.020*	0.095	0.879		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		-	-	0.681			
Wyoming – Missouri	0.276	0.622	*−0.060*	−0.431	0.135	*0.045*	1.029*	0.070		-	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 for Russia and the USA.
[a] Parameters from 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 A.2.1.7: 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	Thresh-old (τ_1)	Sp. Adj. (ρ_2)†	P-value	Thresh-old (τ_2)	Sp. Adj. (ρ_3)†	P-value	Lower	Middle	Upper	Band of Inaction [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				
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*

(continued)

Table A.2.1.7 *(continued)*

Price pair	Lower regime		Middle regime / VECM parameters [a]			Upper regime			Total adjustment [b]			
	Sp. Adj. $(\rho_1)^\dagger$	P-value	Thresh-old (τ_1)	Sp. Adj. $(\rho_2)^\dagger$	P-value	Thresh-old (τ_2)	Sp. Adj. $(\rho_3)^\dagger$	P-value	Lower	Middle	Upper	Band of Inaction [c]
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				
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				

(continued)

Table A.2.1.7 *(continued)*

Price pair	Lower regime			Middle regime / VECM parameters [a]			Upper regime		Total adjustment [b]			
	Sp. Adj. $(\rho_1)^{\dagger}$	P-value	Thresh-old (τ_1)	Sp. Adj. $(\rho_2)^{\dagger}$	P-value	Thresh-old (τ_2)	Sp. Adj. $(\rho_3)^{\dagger}$	P-value	Lower	Middle	Upper	Band of Inaction [c]
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				
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				

(continued)

Table A.2.1.7 *(continued)*

Price pair	Lower regime		Middle regime / VECM parameters [a]				Upper regime		Total adjustment [b]			
	Sp. Adj. $(\rho_1)^\dagger$	P-value	Thresh-old (τ_1)	Sp. Adj. $(\rho_2)^\dagger$	P-value	Thresh-old (τ_2)	Sp. Adj. $(\rho_3)^\dagger$	P-value	Lower	Middle	Upper	Band of Inaction [c]
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				
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				
Statesville – Cofield	−0.161	0.409	*−0.057*	−0.161	0.409	*0.018*	−0.161	0.409	-	-	-	*0.076*

(continued)

Table A.2.1.7 ***(continued)***

Price pair	Lower regime		Middle regime / VECM parameters [a]			Upper regime			Total adjustment [b]			
	Sp. Adj. $(\rho_1)^{\dagger}$	P-value	Thresh-old (τ_1)	Sp. Adj. $(\rho_2)^{\dagger}$	P-value	Thresh-old (τ_2)	Sp. Adj. $(\rho_3)^{\dagger}$	P-value	Lower	Middle	Upper	Band of Inaction [c]
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 for Iowa and North Carolina. Parameters for North Caucasus and West Siberia are by itself estimated on biweekly level.
[a] Parameters from 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 A.2.1.8: Additional production potential in Russia at the regional level

Economic region	Sown area	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.

2.2 DETERMINANTS OF SPATIAL MARKET EFFICIENCY OF GRAIN MARKETS IN RUSSIA: A COMPARISON WITH THE USA

Earlier versions of this paper were presented as:

- Contributed Paper at the 57th Annual Conference of the German Association of Agricultural Economists (GeWiSoLa) "Bridging the Gap between Resource Efficiency and Society's Expectations in the Agricultural and Food Economy", September 13–15, 2017, Munich, Germany.
- Contributed Paper at the XV EAAE Congress "Towards Sustainable Agri-Food Systems: Balancing between Markets and Society", August 29–September 1, 2017, Parma, Italy.
- Contributed Paper at the AAEA Annual Meeting, July 30–August 1, 2017, Chicago, USA.
- Contributed Paper at the IAMO-Forum 2017 "Eurasian Food Economy between Globalization and Geopolitics", June 21–23, 2017, Halle (Saale), Germany.

Study outcomes also constitute a part of the World Bank report:

- World Bank (2018). Europe and Central Asia – The impacts of the El Niño and La Niña on large grain producing countries in ECA: yield, poverty and policy response. Washington, D.C.: World Bank Group.

Determinants of spatial market efficiency of grain markets in Russia

Abstract

Results of an unobserved effects model on the determinants of inter- and intraregional grain market integration in Russia in comparison to the USA makes evident differences in the fundamental mechanisms underlying market integration: While physical trade flows are exclusively dominant in Russia, additional information flows induced by commodity futures markets play a great role in the USA. Policy efforts to improve grain market efficiency in Russia should not be limited to fostering investments in the transportation and trade infrastructure but also the development of market information services and commodity futures markets.

Keywords: wheat markets, regional integration, unobserved effects model, Russia, the USA

1 Introduction

In the beginning of the 21st century, Russia started to export wheat to the world market. The continuous increase in domestic wheat production and the rising share of exports were fostered by the comprehensive devaluation of the Russian Ruble which started in November of 2014. In 2017–18, Russia became the largest wheat exporter in the world much earlier than generally expected, with wheat production amounting to 85 million tons and wheat exports accounting for 21% of global wheat exports (USDA-PSD, 2018).

Wheat production in Russia is distributed among six main production regions. The primary wheat producing region is the North Caucasus region, which has direct access to the ports of the Black Sea—and thus the world market. However, not all regions have this access, especially remote agricultural land in Ural and West Siberia, which are up to 4,000 km away from the Black Sea region. Wheat production in Russia is characterized by large harvest shortfalls due to weather conditions; for example, up to over 60% in the Volga region in 2010–11. Therefore, at present, interregional wheat trade within Russia is of high importance to both equilibrate wheat demand and supply and to cushion domestic price shocks.

It can be expected that Russia's wheat production will further increase because of technological progress and recultivating former agricultural land that was abandoned during the transformation process (Fellmann et al., 2014; Lioubimtseva and Henebry, 2012; Schierhorn et al., 2014; Swinnen et al., 2017). However, variation in the degree of spatial integration of Russia's regional wheat markets with the world wheat markets is large, ranging between 35% and 67% (Götz et al., 2016). In addition, spatial integration of regional wheat markets is very heterogeneous. Especially the wheat export region North Caucasus is only weakly integrated with the other domestic grain producing regions in Russia (Svanidze and Götz, 2019), which limits the mobilization of the additional grain export potential especially in the remote regions. Furthermore, World Bank (2018) points out that the frequency of droughts in Russia is strongly related to the El Niño and La Niña events, reducing grain yields in Russia's largest production regions.

This paper addresses the following research question: Which factors influence the degree of spatial market integration of regional grain markets in Russia? We aim to shed light on the underlying mechanisms of market integration in Russia and to identify the influencing factors. Based on those results we aim to draw policy conclusions on how the functioning of the Russian wheat market could be improved. Russia bears large additional grain production potential, especially in the remote regions. However, the additional wheat production potential not only has to be mobilized but also has to be transformed into additional export potential to further increase Russia's importance for global wheat exports and hence, for global food security. This requires a spatially efficient domestic grain market, ensuring comprehensive and quick transmission of price changes from the grain export to the grain production regions.

We follow the conceptual framework suggested by Svanidze and Götz (2019) and investigate Russia's wheat market in comparison to the corn market of the USA. We choose the corn market rather than the wheat market of the USA because corn is the primary feed grain produced in the USA. Similar to wheat in Russia, corn is also mainly produced and consumed domestically and heavily traded within the USA. Furthermore, grain trade in both countries is characterized by large distances, which is important for the analysis of spatial price relationships. However, in contrast to Russia, where futures markets are quite basic, farmers in the USA heavily engage in well-developed grain futures markets, enabling them to efficiently discover prices and manage price risk.

We conduct the analysis at the interregional and intraregional levels. The interregional analysis centers upon markets in different grain producing regions with large distances to each other (up to 4,000 km), whereas markets within the selected grain producing regions with relatively small distances (up to 1,000 km) are the focus of the intraregional analysis. We study the influence of spatial distance and factors of wheat supply and demand on wheat market integration in Russia compared to the corn market of the USA.

Our study adds to the strand of literature investigating the determinants of spatial price linkages in agricultural commodities markets. In their meta-analysis, Kouyaté and von Cramon-Taubadel (2016) identify the strong negative influence of distance and international borders on spatial price relationships in cereal markets. Ebata et al. (2017) further show that additional increases in distance and travel time to sales markets significantly reduces farm gate prices of beans in Nicaragua and, thus, has a welfare effect on smallholder producers. Zant (2018) provides additional evidence on the importance of railway connections between markets to reduce crop price dispersion in Malawi.

Market characteristics apart from distance and its associated trade costs could also influence spatial price relationships. Besides confirming the negative influence of distance on market integration, Goodwin and

Schroeder (1991) find prices of regional cattle markets of the USA spatially less dependent if both markets in question are of relatively large volume. In addition, the easiness of discovering local cattle prices positively influences the integration of US cattle markets (Schroeder, 1997). Baffes et al. (2017) show that favorable weather conditions decrease domestic prices in the Tanzanian maize market, whereas unfavorable weather conditions have a reverse effect on prices.

Several studies confirm the importance of commodity futures markets for the efficiency of spot markets resulting from high market transparency and liquidity (Adämmer and Bohl, 2018; Garbade and Silber, 1983; Kofi, 1973; McKenzie and Holt, 2002; Peri et al., 2013; Yang and Leatham, 1999). Particularly, Carter and Mohapatra (2008) find that futures markets in the USA serve a price discovery function by reacting first to market information, which is subsequently transmitted to prices in physical commodities markets. Similarly, Santos (2002) confirms that futures markets in the USA induce stabilizing effects on physical grain markets.

The remainder of this paper is structured as follows: Russia's wheat market characteristics are discussed in section 2, whereas the methodological framework and model estimation is addressed in section 3. Section 4 discusses data and section 5 presents empirical results. Finally, section 6 discusses results and provides policy implications.

2 Characteristics of the Russian wheat market

Wheat is the primary grain produced in Russia, constituting 60% of total grain production. Wheat production in Russia is concentrated in a limited, yet spatially protracted area (Fig. 2.2.1). Six economic regions account for more than 90% of total wheat production in Russia. North Caucasus is the largest wheat production region (40%), followed by West Siberia, Volga, and Black Earth (each with a 15% share), while wheat production in Ural and the Central region constitutes 8% and 7% of total wheat production, respectively (Rosstat, 2018).

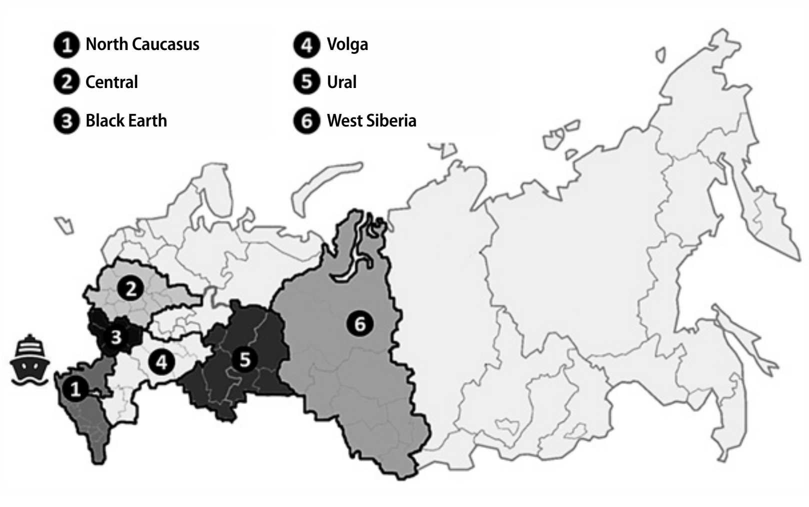

Fig. 2.2.1: Map of grain producing economic regions of Russia

Producing grains to be exported is a rapidly growing sector in Russia. Total wheat exports increased from 0.7 to 42 million tons between 2000 and 2017, paralleling the increase in total wheat production from 35 to 85 million tons in the same time period. Russia has been exporting the most amount of wheat to the world market since 2017, even though it is the fourth largest wheat producer in the world after the European Union, China, and India (USDA-FAS, 2018). Russia exports almost half of its total wheat produced internationally, of which 72% is supplied by North Caucasus, 12% by Volga, 11% by Black Earth, and 4% together by the Central region, Ural, and West Siberia (IKAR, 2018).

The remaining wheat not exported to the world market is available on the domestic market, where it is mainly used for human consumption and livestock feeding. The concentration of human grain consumption in a few city centers (i.e. Moscow, St. Petersburg) and livestock producing regions (Central and Black Earth) requires the transportation of large amounts of wheat from production to consumption sites over long distances.

The Central region with Moscow is the primary wheat deficit region, depending heavily on external supplies. In contrast, North Caucasus almost exclusively supplies wheat to the world market, while its role in domestic trade is rather limited. With its high-capacity sea terminals, North Caucasus also serves as a gate-market for other grain producing regions, particularly Volga and Black Earth, which export 30–40% of what is produced to the world market and supply the rest to the domestic market. In contrast, Ural and West Siberia export less than 5% of their produced wheat internationally, with the latter being the second largest producer of wheat in Russia, but the most remotely located wheat production region. These two regions are located not only far away from the world market, with the distance to the Black Sea ports amounting to 4,000 kilometers, but also the grain consumption regions within Russia. In particular, Moscow is about 2,000–3,000 kilometers away.

Wheat production in Russia is strongly influenced by climatic and weather conditions (Götz et al., 2016). Owing to vast distances and varying production conditions, relatively high yields might be observed in some regions, but relatively low yields in others at the same time. The variation of wheat production within a single region is also generally high.

The Russian grain market is also characterized by frequent government interventions repeatedly restricting grain exports to the world market. For example, an export tax of 40% was implemented during the 2007–8 price peak and wheat exports were completely banned in the 2010–11 drought year. Following a severe currency devaluation, a 15% duty on wheat exports with a minimum levy of 35 Euro/ton was imposed by the Russian government in February of 2015 that lasted until May 15th of the same year.

Rail and road transport are the primary means of wheat transportation in Russia. Rail transport dominates when the transportation distance exceeds 1,000 kilometers, while road transport is preferred for routes up to 500 kilometers. River transportation is quite unusual for grain delivery in Russia. However, transport infrastructure is outdated and insufficient in some regions and differs strongly between regions. For instance, the density of the railway network is highest in the European part of Russia, whereas it is much lower in Ural and West Siberia. Excess crops are often difficult to transport beyond West Siberia, as the only railway track connecting the area to the rest of the country is of low capacity and is shared by many other industries (Scherbanin, 2012). In addition, grain traders regularly complain that the number of grain wagons in peak seasons does not suffice (Gonenko, 2011).

Grain transportation tariffs are generally low in Russia (AEGIC, 2016). Nonetheless, overall transport costs are high, largely due to inadequate transport infrastructure and logistics, which negatively influencing regional wheat trade volumes within Russia (Renner et al., 2014). In addition to high transport costs, grain markets in Russia are also characterized by high business and market risk (PWC, 2015). Trade costs are especially high due to the difficulty of enforcing contracts and unforeseen policy interventions for the grain markets (Götz et al. 2016, 2013).

In this study, we follow a comparative approach and investigate the wheat market of Russia and compare it to the corn market of the USA. Similar to wheat in Russia, corn is also a primarily produced grain in the USA and generally used as a fodder crop. However, large quantities of wheat are transported over long distances in Russia, whereas livestock farms and corn processing facilities such as ethanol plants in the USA are concentrated in the main corn production regions (with the exception of California and Texas), ensuring small transport distances (Haddad et al., 2010).

Market transparency of grain markets is generally high in the USA, where large information flows are induced by the heavy engagement of farmers and traders in commodity futures exchanges. US farmers and grain buyers regularly participate in futures markets to hedge price risk and discover market prices (Mattos, 2017). Since commodity futures markets dominate price discovery processes in the USA (McKenzie and Holt, 2002; Peri et al., 2013), spot market participants follow this information irrespective of their geographic distance to each other. In addition, many private agricultural organizations provide high-frequency market and price information, which is used by farmers to choose locations and traders to sell their grains (Congressional Research Service, 2006).[1] Further, governmental agencies closely monitor market developments and regularly make market and price data publicly available, which improves price adjustment and also lowers market uncertainty in US crop markets (Adjemian et al., 2018).

In contrast, commodity futures markets in Russia are rudimentarily developed due to the unstable market environment, a lack of futures trading skills, and low levels of trust among financial market participants (FAO, 2011). Specifically, wheat export controls have heavily increased uncertainty and are seen as one of the primary factors hampering the development of the commodity futures markets in Russia (Götz et al., 2015). For that reason, grain commodity exchanges in Russia mainly serve as a centralized platform for spot transactions rather than fully functional futures markets. For example, during 2017, only 250 wheat contracts were traded on the Moscow Exchange, which is the largest exchange group in Russia (Moscow Exchange, 2017). In contrast, trade in corn futures averaged 450 thousand contracts in 2017 on the Chicago Board of Trade (CME Group, 2017).

3 Methodology

3.1 Measurement of market integration

Market integration is measured as a degree of price transmission between two spatially separated markets (Fackler and Goodwin, 2001). If regions are involved in trading a good with each other or to the third market, then prices in these regional markets are related through spatial price equilibrium. Even in the case of an absence of physical trade, they might be linked via information flows (Jensen, 2007; Stephens et al., 2012).

1 For example, the data underlying the analysis of the intraregional price transmission for the USA in this study was provided by GeoGrain, which is usually sold as service to farmers and traders.

Price transmission between two spatially separated markets is represented by the price equilibrium equation

$$p_{1t} = \alpha + \beta p_{2t} + \varepsilon_t \quad (1)$$

where p_{1t} and p_{2t} are domestic prices (in the natural logarithm) observed in regional markets 1 and 2; ε_t represents the stationary disturbance term; α denotes the intercept; and β is the coefficient of the long-run price transmission elasticity, characterizing the magnitude of transmission of price shocks from one market to another.

Agricultural price series are often identified as nonstationary processes, which could invalidate inference of the presence of market integration unless the combination of the price series is a stationary process, linking them in the long-run price equilibrium (Engle and Granger, 1987). Therefore, the existence of a cointegration between two nonstationary price series is a precondition for evaluating spatial price relationships. Furthermore, the cointegration equation (1) is built on an implicit assumption that trade costs are stationary, ensuring that the long-run price equilibrium can be correctly identified (Fackler and Goodwin, 2001).

Prior to the estimation of a spatial price relationship, we first identify whether individual price series are nonstationary by using the Dickey-Fuller generalized least squares (DF-GLS) unit root test (Elliott et al., 1996). This is followed by the Johansen test for linear cointegration (Johansen, 1988) to examine the existence of long-run spatial price equilibriums for price pairs. Subsequently, we estimate equation (1) to retrieve price transmission elasticities.

3.2 Determinants of market integration

Fackler and Goodwin (2001) argue that "markets should produce prices that accurately reflect all available information about demand and supply conditions as well as transaction costs" (p. 979). This also implies that market integration is a function of trade costs and supply and demand conditions.

Trade costs comprise all kinds of costs involved in trading a good between two regions; for example, transportation and marketing costs, as well as unmeasurable costs such as search costs and risk premiums resulting from the risks involved in a trading activity (Barrett, 2001).

Supply and demand conditions reflect information on the availability and disappearance of a good in the market. Assuming no changes in the beginning and ending stocks, production and import volumes determine the availability of a good in a market, whereas human consumption, fodder use, and international export represent demand-side factors.

To investigate the influence of various market characteristics on the degree of market integration, we follow a panel data approach and estimate the unobserved effects model

$$\hat{\beta}_{it} = \theta_0 + \theta_1 \text{distance}_i + \sum_{m=1}^{2} [\theta_{2m} \text{grain production}_{mit} + \theta_{3m} \text{export}_{mit} + \theta_{4m} \text{ethanol}_{mit} + \theta_{5m} \text{hog}_{mit} + \theta_{6m} \text{cattle}_{mit} + \theta_{7m} \text{poultry}_{mit} + \theta_{8m} \text{population}_{mit}] + \sum_{t=1}^{T-1} \delta_t \text{year}_t + c_i + \varepsilon_{it} \quad (2)$$

with market pair i, $i = 1, 2, \ldots, N$ (each market pair i composed of regional markets m, $m = 1, 2$) and year t, $t = 1, \ldots, T$. The model is estimated separately for Russia and the USA at the interregional, as well as intraregional, level.

We measure market integration by the value of price transmission elasticity. The dependent variable $\hat{\beta}_{it}$ represents the estimated parameter of the long-run price transmission elasticity from equation (1). The theoretical value of the price transmission elasticity varies between zero and one, with a higher value indicating more strongly integrated markets. Equally, price transmission elasticities might be interpreted in percentage terms between 0–100%.

Similar to Goodwin and Schroeder (1991), we proxy trade costs by market distance. The explanatory variable $distance_i$ measures the average distance between regional markets 1 and 2 for every market pair i. As distance increases, trade costs rise, which decreases the integration of markets between two regions.

Spatial market integration is primarily enforced through trade flows between markets. Therefore, trade flows between the regional markets 1 and 2 are likely to strengthen market integration. We obtained data on the interregional grain trade by rail for Russia and the USA, which approximates data on long-distance grain haulage. However, most of the domestically traded grain in these countries is usually transported by trucks and over short distances. We suspect that by including only railway data in our model estimation, we risk obtaining incorrect estimates of the effect of trade flows on market integration. In addition, trade data is likely to be highly correlated with distance, as found by Schroeder (1997) for the US cattle market.

Instead, we consider supply- and demand-side variables, which determine the likelihood of trade between markets—and, hence, market integration. Grain production quantities in regional markets 1 and 2, $grain\ production_{mit}$, positively influence the strength of market integration. The larger the production in a given region m, $m = 1, 2$, *ceteris paribus,* the more likely this region delivers grain to other grain-deficit regions, and, thus, the higher the market integration.

However, Russia and the USA are both the largest exporters of wheat and corn in the world and some grain (presumably from regions with excess production) is exported internationally. We consider the export orientation of a grain production region as a further factor influencing the integration of domestic grain markets. An enhancing effect on market integration is observed when the domestic price in a production region that is involved in international trade contributes to price discovery in other domestic production regions. The explanatory variable $export_{mit}$ measures wheat and corn exports in regions 1 and 2 in Russia and the USA. However, export data is only available at the interregional level. At the intraregional level, we replace variable $export_{mit}$ with the indicator variable $export_i$, which equals 1 if a market pair i is located in a region involved in international grain exporting, and is equal to 0 otherwise.

Grain, which is available on the domestic markets, is mainly purchased by farms and grain processing industries. Ethanol plants often use corn as a raw material and, therefore, this might influence regional corn market integration in the USA. However, since biofuel production is insignificant in Russia, we only include ethanol production quantities ($ethanol_{mit}$) as an explanatory variable in models estimated for the USA at the interregional level.

Regional markets in Russia and the USA located near large livestock and poultry farms are more likely to be strongly integrated with other regional markets compared to regions with smaller numbers of livestock and poultry inventories. We consider the size of the hog, cattle, and poultry inventories represented by hog_{mit}, $cattle_{mit}$, and $poultry_{mit}$ variables for regions 1 and 2.

In addition, regions with a higher population numbers should be more integrated, as demand for grain is also higher in largely populated areas. The explanatory variable $popul_{mit}$ measures population numbers in regions 1 and 2.

The dummy variable $year_t$ controls for the fixed effect of year t, $t = 1,...,T$ and c_i captures unobserved individual heterogeneity between markets for every market pair i, whereas ε_{it} are idiosyncratic errors.

A random effects estimator is applied to the unobserved effects model when the observed explanatory variables ($\mathbf{x}_{it}$) are not correlated with the unobserved effect c_i, and the fixed effects estimator otherwise. We estimate equation (2) with a random effects estimator in a feasible generalized least squares (FGLS) framework if $\mathrm{Cov}(\mathbf{x}_{it}, c_i) = \mathbf{0}$, for $t = 1, 2,..., T$; otherwise, we apply a fixed effects estimation framework and use pooled ordinary least squares (pooled-OLS), allowing c_i to be correlated with explanatory variables. Since the model's dependent variable represents an estimated parameter rather than an observed variable, we follow the Lewis and Linzer (2005) procedure to treat the accompanying heteroskedasticity by Huber-White corrected robust standard errors.

4 Data

4.1 Price series data

We conduct the price transmission analysis for the wheat market of Russia and the corn market of the USA at two different market levels. A detailed description of the geographic boundaries of the markets is given in Appendix A.

The interregional analysis centers upon price relationships *between* different grain production regions when distances are large. In contrast, price relationships *within* one individual grain production region are the focus of the intraregional analysis when distances are small. We estimate price transmission elasticities based on one marketing year only between July 2010 and June 2016. Price series (each of the price pairs in every marketing year) are trimmed as necessary to the period for which they overlap.

Table 2.2.1 provides a detailed description of the price series used in our price transmission analysis and their sources. Selected grain prices are plotted in Fig. 2.2.2.

Table 2.2.1: Database of grain price series underlying the price transmission analysis

Aggregation level	Estimated time period [a]	Price pairs	Time frequency	Source
		Interregional analysis		
Russia (economic region)	2010–2016	15	Weekly (52 obs.)	Russian Grain Union (2016)
USA (federal state)	2010–2016 [b]	56	Weekly (52 obs.)	USDA-AMS (2016) [e]
		Intraregional analysis		
North Caucasus (oblast)	2010–2016 [c]	6	Biweekly (24 obs.)	Ministry of Agriculture (2016)
West Siberia (oblast)	2010–2016 [d]	15	Biweekly (24 obs.)	Ministry of Agriculture (2016)
Iowa (county)	2010–2016	27	Daily (261 obs.)	GeoGrain (2016)
North Carolina (county)	2010–2016	15	Daily (261 obs.)	GeoGrain (2016)

Note: [a] Price series are estimated for each marketing year separately. [b] Price series for Washington are available only for 2010–2012. [c] Price series for Adygea are available since July 2013. [d] Price series for Kemerovo are available since September 2012, for Novosibirsk since July 2011, and for Omsk since December 2010. [e] GeoGrain for Washington.

For the interregional analysis of the grain markets in Russia, we make use of a unique data set of weekly prices of class three wheat (Ruble/ton) for six economic regions. Correspondingly, we employ weekly corn prices (US dollar/ton) for 15 federal states in the USA.

The analysis of the intraregional market integration for Russia is based on prices observed within two primary wheat production regions. North Caucasus is the primary grain exporting region with direct access to its ports at the Black Sea, whereas West Siberia is primarily involved in the domestic wheat trade due to its large distances to the world market. We consider four price series available for North Caucasus and six price series for West Siberia. Likewise, the intraregional analysis for the USA covers Iowa, a leading corn production and export region, and North Carolina, which, similarly to West Siberia in Russia, mainly supplies its excess corn production to the domestic market. At the intraregional level, Iowa is represented by price series in eight counties and North Carolina by price series in six counties.

Results of the DF-GLS unit root test (Elliott et al., 1996) suggest that all price series included in the interregional and the intraregional analysis are integrated of order one (Appendix B). A test of linear cointegration of the price pairs involved in the interregional and intraregional analysis indicates that linear cointegration is supported for all price pairs in Russia, and 54 (out of 56) and 41 (out of 42) price pairs at the interregional level and intraregional level in the USA, respectively (Appendix C).

Thus, altogether we analyze 15 price pairs for Russia and 54 price pairs for the USA at the interregional level. Similarly, we estimate 21 and 41 pair-wise price relationships at the intraregional level for Russia and the USA, respectively. We report the mean, standard deviation, and the minimum and maximum price transmission elasticities in our data set for each of the price pairs in Russia and the USA separately at the interregional and intraregional level in Appendix D.

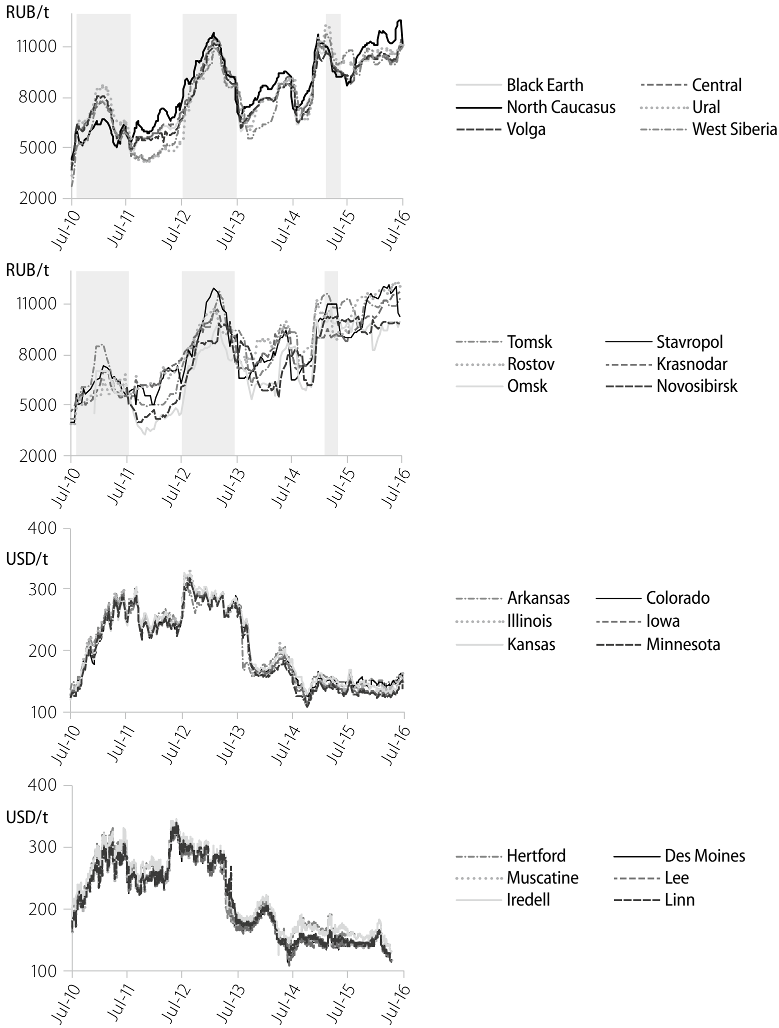

Fig. 2.2.2: Development of selected grain prices at the interregional (left) and intraregional (right) levels in (a) Russia and (b) the USA

Note: The bold area on the graph corresponds to the periods of export ban (Aug 2010–Jul 2011), draught (2012–2013), and export duty (February 2015–May 2015) in Russia.

The price transmission elasticities estimated for every price pair on a yearly basis between 2010 and 2016 provide a measure of market integration and enter the unobserved effects model as a dependent variable. Distribution of the long-run price transmission elasticities is provided in Fig. 2.2.3.

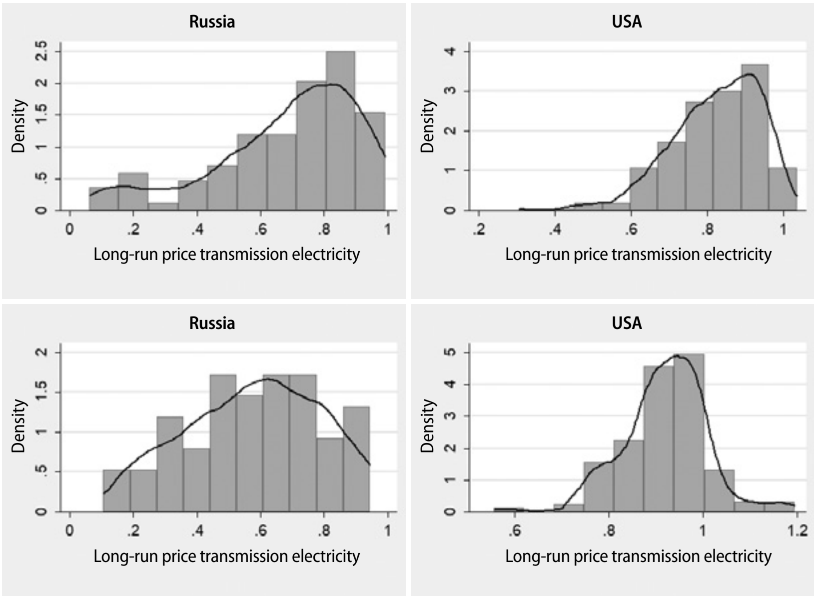

Fig. 2.2.3: Distribution of long-run price transmission elasticities: (a) Interregional analysis, (b) Intraregional analysis

Note: The solid line represents the kernel density plot for the distribution of long-run price transmission elasticities.

The overall distribution of the price transmission elasticities is heavily skewed to the left for Russia and the USA at the interregional level (Fig. 2.2.3, panel a). The estimates range between zero and one and the degree of price transmission is higher than 0.6 in the majority of cases.

However, the right tail is also wider for Russia, indicating a higher incidence of a lower degree of market integration in Russia compared to the USA.

At the intraregional level, the distribution approximates to normal, with parameter estimates centered around 0.6 for Russia and 0.95 for the USA (Fig. 2.2.3, panel b). Moreover, price transmission elasticities are more densely consolidated around the mean for the USA, whereas they are more widely dispersed for Russia.

We consider the distance between markets, grain production, export, ethanol production, cattle, hog, and poultry inventories, along with population, as determinants of the degree of market integration. A detailed description of all variables and their sources is provided in Appendix E, whereas key descriptive statistics of these variables for interregional and intraregional analysis are summarized in Appendix F.

5 Empirical results

In Tables 2.2.2 (pp. 96/97) and 2.2.3 (pp. 98/99) we report parameter estimates for the random effects model to analyze the influence of various market characteristics on market integration at the interregional and intraregional levels in Russia and the USA. The Hausman specification test (Hausman, 1978) confirms that the random effects estimator provides efficient and consistent estimates of true parameters. In general, the estimated models fit this data quite well at the interregional level, especially for Russia. On average, 60% and 30% of the variation in price transmission elasticities is explained by the independent variables at the interregional level in the models for Russia and the USA, respectively. However, the R–squared is relatively low, averaging approximately 0.2 at the intraregional level for Russia and the USA.

In Tables 2.2.2 and 2.2.3 we show estimates for various model specifications, as some variables are highly correlated and the parameter estimates of these correlated predictors are unlikely to be meaningful. Pearson's pairwise correlation statistics (Appendix G) indicate that grain production and export volume are generally highly correlated in both countries, as are inventories of hog, cattle, and poultry. A high correlation is also evident between livestock inventories (hog, cattle, and poultry) and grain production and export. Distance is the only variable uncorrelated with the other explanatory variables.

Therefore, to ensure a rigorous econometric analysis, we estimate a panel data model for different combinations of explanatory variables; however, all of them include distance as one of the explanatory variables. In models (1) to (6), we consider demand- and supply-side variables one by one in each of the model specifications. Finally, we estimate all variables together in model (7). For each model specification, we subsequently evaluate multicollinearity between explanatory variables (Appendix H). Variance inflation factors suggest that high multicollinearity is present in model (7) for Russia and the USA at the interregional and intraregional levels. However, multicollinearity is not present in models (1) to (6), indicating that these models are well specified in this regard.

At the interregional level (Table 2.2.2), the coefficient estimates are not generally interpretable for model (7), confirming results of collinearity diagnostics. For instance, the estimated effect of distance is statistically insignificant for Russia in model (7), although its effect is significant in models (1) to (6). For the USA, the estimated effect of grain production reverses in model (7), indicating that these models suffer from multicollinearity. Thus, we limit our discussion of the estimated parameters at the interregional level to models (1) to (6).

Results of the analysis at the interregional level based on models (1) to (6) in Table 2.2.2 indicate a statistically significant negative influence of distance on the degree of market integration in both countries; however, the impact is two times higher in Russia compared to the USA. This implies that a ceteris paribus increase in distance between markets by 1,000 kilometers decreases the long-run price transmission elasticity by 8–10% in Russia and 4–5% in the USA.

Furthermore, interregional market integration decreases in Russia if a region exports one additional million tons of wheat to the world market (parameter estimate of $export_1$, which contains export values of the largest wheat export region, North Caucasus). For example, North Caucasus has increased wheat exports by three million tons from 2013–2014, which corresponds to a decrease in market integration by 1.5%. However, export values from other smaller-scale export regions ($export_2$) positively influence market integration in Russia. Export values also positively influence interregional market integration in the USA, particularly from the "corn belt" area states ($export_2$).

Coefficient estimates of grain production ($grain\ production_1$) in model (2) for Russia mimic the influence of the export variable $export_1$ on market integration. Particularly, increased production translates into lower integration of wheat markets in Russia. In contrast, larger corn production leads to stronger integrated markets in the USA. This "overlapping" effect is presumably caused by the high correlation between production and export quantities. For Russia, the estimated negative influence of production on domestic market integration implicitly reflects the effect of the largest export region's disintegration in domestic markets (as confirmed by the negative value of $export_1$) rather than the negative influence of production quantities by itself.

As expected, results show that ethanol production positively influences corn market integration in the USA. Further, a larger number of hog inventories in one of the regions implies a stronger transmission of prices between two spatially separated markets in Russia and the USA. In addition, the magnitude and direction of this effect are comparable between countries. An increase in hog inventory by one million heads increases price transmission by 3–4% in both of the countries. In the USA, cattle inventory also has a positive influence on market integration, whereas this effect is negative for Russia. Estimated parameters are also negative for poultry inventories in both countries. For a potential explanation of this negative effect, we speculate that these particular grains (wheat in Russia and corn in the USA) are not intensively used in cattle and poultry feeding. Regarding population, results suggest that this variable has no significant effect on market integration, neither in Russia nor the USA.

At the intraregional level (Table 2.2.3), we also limit the discussion of the estimated parameters to models (1) to (6) to ensure comparability of

Table 2.2.2: Estimated parameters of the random effects model: interregional analysis

	Dependent variable: long-run price transmission elasticity						
	Russia						
Explanatory variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Distance	**−0.083*****	**−0.097*****	**−0.102*****	**−0.098*****	**−0.102*****	**−0.103*****	−0.038
$Export_1$	**−0.005***						**0.015****
$Export_2$	**0.052****						**0.166****
Grain $production_1$		−0.006***					−0.010
Grain $production_2$		−0.007					**−0.049*****
$Ethanol_1$							
$Ethanol_2$							
Hog_1			**0.041*****				0.030
Hog_2			−0.018				−0.086
$Cattle_1$				**−0.052*****			0.019
$Cattle_2$				**−0.043****			**−0.167****
$Poultry_1$					**−0.061****		**−0.160****
$Poultry_2$					−0.018		−0.290
$Population_1$						0.017	−0.006
$Population_2$						−0.032	0.016
Intercept	**0.668*****	**0.806*****	**0.555*****	**0.944*****	**0.769*****	**0.723*****	**1.626*****
Year dummies	yes	yes	yes	yes	yes	yes	yes
N total obs.	90	90	90	90	90	90	90
R-squared	0.58	0.58	0.57	0.60	0.58	0.56	0.71
Hausman test: fixed and random effects [a)]	8.8 (0.27)	10.4 (0.17)	0.5 (0.99)	0.1 (1.00)	1.7 (0.97)	3.8 (0.82)	16.8 (0.47)

Note: Parameter estimates significant at least at 10% are marked in bold. [a)] p-values in parentheses.
*** p<0.01, ** p<0.05, *p<0.10.

USA							
(1)	(2)	(2′)	(3)	(4)	(5)	(6)	(7)
−0.043* **	**−0.044*** **	**−0.048*** **	**−0.036*** **	**−0.045*** **	**−0.047*** **	**−0.051*** **	**−0.042*** **
0.026							0.062
0.005 **							**0.011* **
	0.003						−0.012
	**0.001* **						−0.003
		0.006* **					**0.019*** **
		0.000					0.001
			0.031* **				**0.045*** **
			−0.001				0.004
				0.003* **			**−0.010*** **
				−0.002			**0.008* **
					−0.002* **		−0.001
					−0.001		**−0.008* **
						0.001	−0.000
						0.002	−0.009
0.828* **	**0.838*** **	**0.849*** **	**0.828*** **	**0.860*** **	**0.882*** **	**0.858*** **	**0.778*** **
yes	yes	yes	yes	yes	yes	yes	yes
296	296	296	296	296	296	296	296
0.31	0.30	0.30	0.32	0.30	0.30	0.29	0.38
6.4 (0.49)	3.9 (0.69)	10.9 (0.15)	2.9 (0.89)	3.9 (0.79)	5.9 (0.56)	18.7 (0.01)	14.39 (0.70)

Table 2.2.3: Estimated parameters of the random effects model: intraregional analysis

	Dependent variable: long-run price transmission elasticity						
	Russia						
Explanatory variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Distance	**−0.123****	**−0.107****	**−0.107****	**−0.138****	**−0.124****	**−0.091***	**−0.149*****
Exporter (dummy var.)	−0.019						−0.092
Grain $production_1$		−0.013					0.002
Grain $production_2$		0.012					−0.009
Hog_1			0.280				−0.145
Hog_2			−0.187				0.224
$Cattle_1$				−0.002			−0.002
$Cattle_2$				−0.001			**−0.003****
$Poultry_1$					−0.005		0.007
$Poultry_2$					−0.000		−0.012
$Population_1$						−0.003	−0.002
$Population_2$						0.001	0.005
Intercept	**0.583*****	**0.563*****	**0.583*****	**0.680*****	**0.626*****	**0.626*****	**0.655*****
Year dummies	yes	yes	yes	yes	yes	yes	yes
N total obs.	90	90	90	90	90	90	90
R-squared	0.17	0.18	0.21	0.18	0.17	0.19	0.25
Hausman test: fixed and random effects [a)]	−0.4 (1.00)	2.1 (0.95)	1.3 (0.99)	2.7 (0.91)	4.0 (0.78)	5.7 (0.57)	5.5 (0.99)

Note: Parameter estimates significant at least at 10% are marked in bold. [a)] p-values in parentheses.
*** p<0.01, ** p<0.05, *p<0.10.

USA						
(1)	(2)	(3)	(4)	(5)	(6)	(7)
−0.102* **	**−0.089*** **	**−0.180*** **	**−0.117*** **	**−0.114*** **	**−0.123*** **	−0.058
0.042* **						**0.068*** **
	0.077* **					**0.040* **
	−0.028					−0.014
		0.008				**−0.109*** **
		0.113* **				−0.032
			0.014* **			**0.012*** **
			0.010* **			**0.008*** **
				−0.005* **		0.001
				0.003		**0.008*** **
					0.000	−0.003
					0.000	−0.004
0.932* **	**0.944*** **	**0.962*** **	**0.885*** **	**0.969*** **	**0.964*** **	**0.841*** **
yes	yes	yes	yes	yes	yes	yes
252	252	252	252	252	252	252
0.21	0.19	0.19	0.21	0.18	0.14	0.29
0.0 (1.00)	4.5 (0.72)	0.0 (1.00)	2.5 (0.93)	0.0 (1.00)	0.1 (1.00)	2.7 (0.99)

the estimated effects across different levels of market analysis. Estimation results indicate that, in contrast to the interregional analysis, the influence of distance is, to a large extent, comparable between Russia and the USA at the intraregional level. An increase in distance of 1,000 km decreases the long-run price transmission elasticity by approximately 12% in Russia and 10% in the USA. However, when assessing the change in coefficient estimates within the countries, the influence of distance increases by 2.5 times in the USA at the intraregional level compared to the interregional level, whereas this effect cannot be differentiated between the levels of analysis in Russia. The difference of the influence of distance on market integration in Russia and the USA at the two levels of market analysis provides further evidence of the dissimilarity in the underlying fundamental mechanism of market integration, which we subsequently discuss in depth in the next section.

Concerning the influence of export region at the intraregional level, we find that the coefficient estimate of the export region is not statistically significant for Russia, whereas in the USA market integration is 4.2% higher on average between markets that are located in the export region.

In contrast to the interregional analysis, results at the intraregional level indicate that the size of livestock and poultry inventories does not influence market integration in Russia. However, market integration is strengthened at the intraregional level in the USA with an increasing number of livestock (hog and cattle) inventories, whereas the increase in poultry inventories has an adverse effect on market integration. We relate these opposing effects of hog and cattle inventories across countries to the spatial organization of markets.[2] In the USA, livestock farms are located near cornfields to ensure efficient logistics, which is reflected in the positive influence of cattle and hog inventories on market integration at the intraregional level in the USA. In contrast, grain production and consumption areas are separated by relatively large distances in Russia, which is confirmed by the statistically insignificant influence of hog and

2 In the USA: A positive effect of hog and cattle inventories at the interregional and intraregional levels. In Russia: A positive (negative) effect of hog (cattle) inventories at the interregional level and no influence at the intraregional level.

cattle inventories at the intraregional level. The population once again exhibits no effect on intraregional market integration in both Russia and the USA.

In the next step, we evaluate the parameter estimates of the year dummies for Russia and the USA as presented in Table 2.2.4 for model (1) only, as estimates of year dummies are highly comparable in all models (1) to (7).

Table 2.2.4: Estimated effects of year dummies in model (1)

	Interregional analysis		Intraregional analysis	
	Russia	USA	Russia	USA
Year dummies: 2011/12=base year				
2010/11	**0.178****	**0.082*****	0.159	0.002
2012/13	**0.291*****	**0.075*****	0.075	**−0.049*****
2013/14	**0.255*****	**0.083*****	**0.177****	**−0.034*****
2014/15	**0.308*****	−0.024	0.061	0.023
2015/16	−0.017	**−0.067****	0.019	−0.024*

Note: Estimates of year dummies for models (2) to (7) are available from the authors upon request. Parameter estimates significant at least at 10% are marked in bold. *** $p<0.01$, ** $p<0.05$, * $p<0.10$

The estimated effect suggests a two-three times larger temporal variation in the degree of market integration in Russia compared to the USA at the interregional level. A smaller variation in the degree of price co-movement in the USA suggests that market conditions are more stable in US corn markets. In contrast, a higher variation in the degree of wheat market integration in Russia might be attributable to frequent harvest shortfalls and governmental policy interventions. In comparison with the base year of 2011–12 (free trade regime), market integration was 18% higher in 2010–11, when the Russian government completely banned the export of grain, and 31% higher in 2014–15, when the government imposed a wheat export duty. Market integration also increased in 2012–13 when severe drought caused widespread harvest shortfalls, but wheat exports were not restricted by political market interventions.

Not surprisingly, the parameters of year dummies for Russia are less often statistically significant at the intraregional level since the market environment and weather conditions are more uniform within the production regions. For the USA, a number of parameters of year dummies are identified as statistically significant, although they are still about four to five times smaller than the parameter estimates obtained for Russia.

6 Discussion of results and policy implications

In this study we have assessed the influence of market characteristics on the integration of the Russian wheat market by comparing it to the corn market of the USA. First, for this purpose, we utilized a price transmission approach to obtain the quantitative measure of grain market integration in Russia and the USA. We then estimated the influence of various factors on the degree of market integration using a random effects model. The model considers the influence of distance, grain production, export volume (exporter region), and domestic demand-side factors on the degree of price transmission between spatially separated grain markets in Russia and the USA. We employed panel data for the 2010–2016 period at the interregional and intraregional levels for Russia and the USA.

6.1 Discussion of results

The analysis has made evident that distance is a strong predictor of market integration. At the interregional level, the influence of distance is considerably higher in Russia than in the USA. However, at the intraregional level, the influence of distance is comparable in both of the countries. These results provide evidence for the dissimilarity of the underlying fundamental mechanism of market integration between Russia and the USA.

It is well documented in trade literature that distance accounts for variable trade costs related to transferring goods from one market to another. We argue that distance plays a major role in the spatial market integration if markets are primarily linked via physical trade flows (rather than information flows). However, if a price comovement between markets is predominantly guided by information flows (and not by physical trade), then distance will play a rather minor role in explaining the strength of price transmission between markets since the distance cannot account for "information costs". We apply this line of reasoning to grain markets in Russia and the USA to explain the different influence of distance on the integration of grain markets in these countries.

In Russia, the physical trade of wheat mainly fosters market integration at the interregional level, as wheat is heavily transported not only over small distances, but also over distances up to 4,000 km from production to consumption regions (for example, from West Siberia to the Central region). In contrast, information flows play a rather minor role (if any) for the integration of the Russian grain market due to the rudimentary development of futures markets (FAO, 2011). Also, the availability of market and price information based on market monitoring activities by governmental and private agencies is generally low in Russia. Correspondingly, distance has a strong negative influence on market integration at the interregional and intraregional levels in Russia.

Unlike Russia, information flows, in addition to physical trade flows, are of primary importance for market integration at the interregional level in the USA. The efficiency of futures markets and their role in the formation of spot prices explains the relatively small influence of distance on corn market integration in the USA at the interregional level. In contrast, corn is heavily physically traded over small distances within production regions in the USA. For instance, corn consumption industries such as ethanol and livestock facilities, are located around the cornfields. This explains the identified high influence of distance on intraregional market integration in the USA, similar to Russia.

Panel data analysis indicates a negative influence of the largest export region on interregional market integration in Russia. On the other hand, exports from the exporting regions of relatively minor importance increase integration of the Russian wheat market. Results show that exports from North Caucasus, which account for almost 80% of exported grain from Russia, decrease market integration of this region with the other five grain production regions. This finding is in line with the results by Götz et al. (2016) indicating that price developments in North Caucasus are strongly influenced by prices on the world market, and Svanidze and Götz (2019), which further confirm that price developments in North Caucasus are only transmitted to other grain production regions of Russia to a limited extent. In contrast, the export region has an enhancing effect on market integration in the USA, indicating that domestic prices of primary export regions contribute to price discovery in other regions not involved in international trade.

Regarding domestic demand-side variables, we identify a strong positive influence of hog inventories on interregional market integration in Russia. Pork production is a rapidly increasing sector in Russia due to the government's comprehensive subsidization of investments in this sector since 2012 (Götz and Jaghdani, 2017). If this tendency in pork production continues, market integration will further strengthen between the grain and hog producing regions of Russia. Further, we interpret the positive influence of cattle and hog inventories at the intraregional level in the USA (this effect is not identified for wheat markets in Russia) as additional evidence that efficient organization of markets ensures small travel distances and operational logistics.

Our results also show that the Russian wheat market, in contrast to the US corn market, is characterized by large temporal variations in price transmission elasticities resulting from frequent government interventions and weather-related harvest shortfalls. The results imply that price developments in the wheat markets of Russia are vulnerable to frequently changing governmental policies and weather events.

6.2 Policy implications

These research findings offer several policy implications aimed at improving the spatial market integration of wheat markets in Russia to ensure the full mobilization of grain export and production potential, especially in remote areas.

As distance influences regional wheat market integration in Russia, substantial investments in the grain market and transportation infrastructure is required to improve the integration of domestic markets, especially with the export region. Nonetheless, the development of transportation and trade infrastructure is not sufficient for improving Russia's wheat market efficiency since, until now, commodity futures markets have only been rudimentarily developed. Without upgraded market information services and the development of commodity futures markets, the spatial market efficiency of grain markets in Russia cannot be improved to a level similar to the corn market of the USA.

As another policy measure, the wheat supply chain could be restructured in marginally located regions. Livestock production might be taken up in remote grain production regions with excess grain production. Instead of exporting wheat to the world market, they might rather export meat profitably to the world market.

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APPENDIX A. GEOGRAPHIC BOUNDARIES OF MARKETS

Geographic boundaries of markets are as follows:

- *Economic regions* for wheat markets of Russia and *federal states* for corn markets of the USA at the interregional level.
- *Oblasts* (located in North Caucasus and West Siberia) for wheat markets of Russia and *counties* (located in Iowa and North Carolina) for corn markets of the USA at the intraregional level.

Table A.2.2.1: List of selected markets

No.	Interregional analysis		Intraregional analysis			
	Russia (economic regions)	USA (federal states)	North Caucasus (oblasts)	West Siberia (oblasts)	Iowa (counties)	North Carolina (counties)
1	Central	Arkansas	Adygea	Altai	Clinton	Hertford
2	Black Earth	California	Krasnodar	Kemerovo	Des Moines	Iredell
3	North Caucasus	Colorado	Rostov	Novosibirsk	Lee	Montgomery
4	Ural	Illinois	Stavropol	Omsk	Linn	Scotland
5	Volga	Iowa		Tomsk	Mahaska	Washington
6	West Siberia	Kansas		Tyumen	Muscatine	Wilkes
7		Minnesota			Palo Alto	
8		Missouri			Scott	
9		Nebraska				
10		Oklahoma				
11		South Dakota				
12		Texas				
13		Virginia				
14		Washington				
15		Wyoming				

APPENDIX B. DF-GLS UNIT ROOT TEST

Table B.2.2.1: DF-GLS unit root test for prices in levels and first differences

Price series	Lag	T-statistic	Δ Price series	Lag	T-statistic
			Russia (interregional analysis)		
Central	1	−0.249	Δ Central	0	−6.068***
N. Caucasus	1	−2.186	Δ N. Caucasus	0	−8.2006***
Black Earth	1	−2.262	Δ Black Earth	0	−7.307***
Volga	2	−2.113	Δ Volga	1	−6.422***
Ural	2	−2.314	Δ Ural	3	−6.138***
W. Siberia	5	−1.937	Δ W. Siberia	4	−6.668***
			USA (interregional analysis)		
Arkansas	0	−0.987	Δ Arkansas	1	−8.003***
California	0	−0.806	Δ California	0	−16.834***
Colorado	1	−0.838	Δ Colorado	1	6.905***
Illinois	1	−0.899	Δ Illinois	1	7.297***
Iowa	1	−0.791	Δ Iowa	1	−7.590***
Kansas	1	−0.727	Δ Kansas	1	6.690***
Minnesota	1	−0.816	Δ Minnesota	1	−7.776***
Missouri	0	−0.795	Δ Missouri	1	−8.110***
Nebraska	1	−0.843	Δ Nebraska	0	−10.700***
Oklahoma	1	−0.764	Δ Oklahoma	1	−7.217***
S. Dakota	1	−0.799	Δ S. Dakota	1	−8.056***
Texas	1	−0.766	Δ Texas	1	−6.340***
Virginia	0	−0.553	Δ Virginia	1	−7.764***
Washington	0	−1.176	Δ Washington	0	−7.804***
Wyoming	1	−0.776	Δ Wyoming	1	−6.975***
			North Caucasus (intraregional analysis)		
Adygea	1	−2.607	Δ Adygea	0	−6.411***
Krasnodar	1	−2.168	Δ Krasnodar	0	−7.853***
Stavropol	0	−2	Δ Rostov	0	−12.911***
Rostov	0	−2.114	Δ Stavropol	0	−12.041***

West Siberia (intraregional analysis)					
Altai	1	−2.424	Δ Altai	0	−7.501***
Kemerovo	1	−2.260	Δ Kemerovo	0	−5.455***
Novosibirsk	0	−1.662	Δ Novosibirsk	0	−4.937***
Omsk	1	−0.881	Δ Omsk	0	−3.143**
Tomsk	1	−2.269	Δ Tomsk	0	−8.263***
Tyumen	0	−1.709	Δ Tyumen	1	−3.532***
Iowa (intraregional analysis)					
Cedar Rapids	1	−0.830	Δ Cedar Rapids	1	−14.167***
Clinton	1	−0.825	Δ Clinton	1	−18.599***
Davenport	0	−1.007	Δ Davenport	1	−22.297***
Eddyville	1	−0.849	Δ Eddyville	1	−21.800***
Emmetsburg	0	−0.823	Δ Emmetsburg	1	−22.051***
Keokuk	0	−0.888	Δ Keokuk	1	−8.682***
Muscatine	1	−0.863	Δ Muscatine	1	−18.727***
W. Burlington	0	−0.798	Δ W. Burlington	1	−13.896***
North Carolina (intraregional analysis)					
Candor	1	−1.165	Δ Candor	1	−29.209***
Cofield	1	−1.022	Δ Cofield	1	−27.710***
Creswell	1	−0.986	Δ Creswell	1	−29.082***
Laurinburg	1	−1.249	Δ Laurinburg	1	−13.604***
Roaring River	1	−0.988	Δ Roaring River	1	−29.407***
Statesville	1	−1.077	Δ Statesville	1	−30.084***

Note: Lag length selection is based on Schwarz Information Criterion. Deterministic component is constant and linear trend.
* $p<0.10$, ** $p<0.05$, *** $p<0.01$

APPENDIX C. TEST OF LINEAR COINTEGRATION

Table C.2.2.1: Test of linear cointegration: Interregional analysis

Price pair	Test specification	Johansen test (1988) †	
		Trace test statistic	P-value
Russia			
Central – Black Earth	1 lag, intercept	45.022*** / 0.561	0.000 / 0.516
Central – Volga	2 lags, intercept	22.212** / 6.483	0.027 / 0.157
Central – Ural	2 lags, intercept	20.612** / 6.184	0.045 / 0.177
Central – W. Siberia	3 lags, intercept	30.729*** / 4.922	0.001 / 0.292
N. Caucasus – Central	2 lags, intercept	22.371** / 6.361	0.025 / 0.165
N. Caucasus – Black Earth	2 lags, intercept	20.364** / 5.711	0.048 / 0.214
N. Caucasus – Volga	1 lag, intercept	26.244*** / 6.308	0.007 / 0.168
N. Caucasus – Ural	1 lag, intercept	21.086** / 7.629*	0.038 / 0.097
N. Caucasus – W. Siberia	1 lag, intercept	24.663** / 6.455	0.012 / 0.158
Black Earth – Volga	2 lags, intercept	24.065** / 7.971*	0.014/ 0.084
Black Earth – Ural	1 lag, intercept	25.761*** / 8.442*	0.008 / 0.068
Black Earth – W. Siberia	3 lags, intercept	30.577*** / 5.183	0.001 / 0.264
Volga – Ural	4 lags, intercept	17.226** / 2.180	0.027 / 0.140
Volga – W. Siberia	4 lags, intercept	23.260** / 1.576	0.019 / 0.860
Ural – W. Siberia	2 lags, intercept	23.195** / 6.011	0.019 / 0.190
USA			
Arkansas – Illinois	1 lag, intercept	31.220*** / 2.120	0.000 / 0.150
Arkansas – Iowa	1 lag, intercept	27.770*** / 2.100	0.000 / 0.150
Arkansas – Kansas	1 lag, intercept	26.360*** / 2.510	0.000 / 0.110
Arkansas – Minnesota	1 lag, intercept	27.090*** / 1.930	0.000 / 0.790
Arkansas – Missouri	1 lag, intercept	34.470*** / 2.490	0.000 / 0.680
Arkansas – Nebraska	1 lag, intercept	32.900*** / 2.220	0.000 / 0.730
Arkansas – S. Dakota	1 lag, intercept	30.040*** / 1.860	0.000 / 0.810
California – Illinois	0 lag, intercept	23.150** / 8.930	0.020 / 0.050
California – Iowa	1 lag, intercept	28.950*** / 1.410	0.000 / 0.240
California – Kansas	1 lag, intercept	38.080*** / 1.420	0.000 / 0.230
California – Minnesota	1 lag, intercept	20.640*** / 1.520	0.010 / 0.220

California – Missouri	1 lag, intercept	17.440** / 1.540	0.030 / 0.210
California – Nebraska	1 lag, intercept	19.110*** / 1.470	0.010 / 0.230
California – S. Dakota	1 lag, intercept	18.940*** / 1.660	0.010 / 0.200
Colorado – Illinois	1 lag, intercept	28.470*** / 2.070	0.000 / 0.150
Colorado – Iowa	1 lag, intercept	33.030*** / 1.370	0.000 / 0.240
Colorado – Kansas	1 lag, intercept	18.220** / 2.150	0.020 / 0.140
Colorado – Minnesota	1 lag, intercept	30.350*** / 1.440	0.000 / 0.230
Colorado – Missouri	1 lag, intercept	31.835*** / 1.746	0.000 / 0.186
Colorado – Nebraska	1 lag, intercept	36.150*** / 1.606	0.000 / 0.205
Colorado – S. Dakota	1 lag, intercept	40.877*** / 1.642	0.000 / 0.200
Oklahoma – Illinois	4 lags, intercept	18.091** / 3.309	0.020 / 0.069
Oklahoma – Iowa	1 lag, intercept	20.316*** / 1.383	0.009 / 0.240
Oklahoma – Kansas	1 lag, intercept	48.773*** / 1.973	0.000 / 0.160
Oklahoma – Minnesota	1 lag, intercept	19.838*** / 1.562	0.010 / 0.211
Oklahoma – Missouri	1 lag, intercept	17.351** / 1.761	0.026 / 0.185
Oklahoma – Nebraska	1 lag, intercept	21.862*** / 1.620	0.005 / 0.203
Oklahoma – S. Dakota	1 lag, intercept	19.035** / 1.838	0.014 / 0.175
Texas – Illinois	0 lag, intercept & trend	30.326** / 8.495	0.013 / 0.214
Texas – Iowa	1 lag, intercept	16.339** / 1.567	0.037 / 0.211
Texas – Kansas	1 lag, intercept	23.154*** / 1.967	0.003 / 0.161
Texas – Minnesota	1 lag, intercept	12.368 / 1.511	0.140 / 0.219
Texas – Missouri	0 lag, intercept	18.135** / 1.829	0.020 / 0.176
Texas – Nebraska	1 lag, intercept	15.513** / 1.682	0.050 / 0.195
Texas – S. Dakota	1 lag, intercept	8.575 / 1.602	0.406 / 0.206
Virginia – Illinois	1 lag, intercept	12.979** / 0.748	0.039 / 0.445
Virginia – Iowa	1 lag, intercept	15.0876* / 0.821	0.058 / 0.365
Virginia – Kansas	1 lag, intercept	21.104*** / 0.883	0.001 / 0.402
Virginia – Minnesota	1 lag, intercept	13.653* / 0.669	0.093 / 0.414
Virginia – Missouri	1 lag, intercept	14.351* / 0.594	0.074 / 0.441
Virginia – Nebraska	1 lag, intercept	16.258** / 0.522	0.038 / 0.470
Virginia – S. Dakota	0 lag, intercept	16.551** / 0.393	0.035 / 0.531
Washington – Illinois	4 lags, intercept	31.330*** / 8.572*	0.001 / 0.065
Washington – Iowa	2 lags, intercept	25.258*** / 8.546*	0.009 / 0.065
Washington – Kansas	3 lags, intercept	26.924*** / 7.169	0.005 / 0.118
Washington – Minnesota	3 lags, intercept & trend	27.977** / 11.898*	0.027 / 0.063
Washington – Missouri	3 lags, intercept & trend	26.373** / 10.329	0.043 / 0.113
Washington – Nebraska	3 lags, intercept & trend	26.873** / 12.168*	0.038 / 0.057
Washington – S. Dakota	3 lags, intercept & trend	29.303** / 11.169*	0.018 / 0.083
Wyoming – Illinois	1 lag, intercept	23.293** / 2.488	0.019 / 0.680

Wyoming – Iowa	1 lag, intercept	25.597*** / 1.494	0.008 / 0.875
Wyoming – Kansas	1 lag, intercept	14.015* / 1.216	0.083 / 0.270
Wyoming – Minnesota	1 lag, intercept	22.575** / 1.749	0.024 / 0.827
Wyoming – Missouri	1 lag, intercept	20.962** / 1.675	0.040 / 0.841
Wyoming – Nebraska	1 lag, intercept	24.113** / 1.516	0.014 / 0.871
Wyoming – S. Dakota	1 lag, intercept	22.892*** / 1.998	0.003 / 0.158

Note: † The first number in the column refers to the hypothesis H_0: no cointegration | H_1: at least one cointegration equation. The second number in the columns refers to the hypothesis H_0: one cointegration equation | H_1: two cointegration equations.
* p<0.10, ** p<0.05, *** p<0.01

Table C.2.2.2: Test of linear cointegration: Intraregional analysis

Price pair	Test specification	Johansen test (1988) †	
		Trace test statistic	P-value
North Caucasus			
Adygea – Krasnodar	0 lag, intercept & trend	30.113** / 6.020	0.014 / 0.458
Adygea – Rostov	1 lag, intercept	16.634** / 2.052	0.034 / 0.152
Adygea – Stavropol	3 lags, intercept	12.690** / 0.967	0.043 / 0.377
Krasnodar – Rostov	1 lags, intercept & trend	24.328** / 6.714	0.013 / 0.142
Stavropol – Krasnodar	1 lags, intercept & trend	24.173** / 4.790	0.014 / 0.307
Stavropol – Rostov	2 lags, intercept & trend	19.475* / 4.869	0.064 / 0.298
West Siberia			
Kemerovo – Altai	2 lags, intercept	20.459** / 4.709	0.047 / 0.317
Kemerovo – Novosibirsk	2 lags, intercept	20.208* / 2.996	0.051 / 0.581
Kemerovo – Omsk	2 lags, intercept	23.018** / 4.362	0.020 / 0.361
Kemerovo – Tomsk	2 lags, intercept	19.768* / 4.138	0.058 / 0.392
Novosibirsk – Altai	2 lags, intercept	47.956*** / 6.444	0.000 / 0.159
Novosibirsk – Omsk	1 lag, intercept	30.424*** / 2.001	0.000 / 0.157
Tomsk – Novosibirsk	1 lag, intercept	44.677*** / 2.696	0.000 / 0.101
Tomsk – Altai	2 lags, intercept	29.514*** / 3.237*	0.000 / 0.072
Tomsk – Omsk	1 lag, intercept	20.316*** / 1.811	0.009 / 0.178
Altai – Omsk	3 lags, intercept	22.558** / 2.936	0.024 / 0.593
Tyumen – Altai	1 lag, intercept	32.427*** / 6.740	0.001 / 0.141
Tyumen – Kemerovo	0 lag, intercept	21.490*** / 2.434	0.006 / 0.119
Tyumen – Novosibirsk	1 lag, intercept	14.775* / 14.775	0.064 / 0.164
Tyumen – Omsk	1 lag, intercept	27.366*** / 2.743	0.004 / 0.630
Tyumen – Tomsk	1 lag, intercept	14.544** / 0.394	0.021 / 0.594

Iowa			
Cedar Rapids – Emmetsburg	1 lag, intercept	79.629*** / 0.368	0.000 / 0.544
Clinton – Cedar Rapids	1 lag, intercept	192.087 / 0.469	0.468 / 0.493
Clinton – Davenport	1 lag, intercept	54.694*** / 0.599	0.000 / 0.439
Clinton – Emmetsburg	1 lag, intercept	35.509*** / 0.348	0.000 / 0.556
Clinton – Muscatine	1 lag, intercept	112.894*** / 0.466	0.000 / 0.495
Davenport – Cedar Rapids	1 lag, intercept	55.166*** / 0.815	0.000 / 0.367
Davenport – Emmetsburg	1 lag, intercept	27.861***/ 0.385	0.000 / 0.535
Eddyville – Cedar Rapids	1 lag, intercept	117.718*** / 0.421	0.000 / 0.517
Eddyville – Clinton	1 lag, intercept	107.163*** / 0.367	0.000 / 0.545
Eddyville – Davenport	1 lag, intercept	73.208*** / 0.615	0.000 / 0.433
Eddyville – Emmetsburg	1 lag, intercept	60.025*** / 0.304	0.000 / 0.581
Eddyville – Keokuk	1 lag, intercept	78.104*** / 0.390	0.000 / 0.532
Eddyville – Muscatine	1 lag, intercept	119.235*** / 0.478	0.000 / 0.489
Keokuk – Clinton	1 lag, intercept	55.502*** / 0.417	0.000 / 0.518
Keokuk – Davenport	1 lag, intercept	85.101*** / 0.497	0.000 / 0.481
Keokuk – Emmetsburg	2 lags, intercept	16.416** / 0.326	0.036 / 0.568
Keokuk – Muscatine	1 lag, intercept	64.532*** / 0.510	0.000 / 0.475
Muscatine – Cedar Rapids	1 lag, intercept	104.792*** / 0.568	0.000 / 0.451
Muscatine – Davenport	1 lag, intercept	67.269*** / 0.725	0.000 / 0.394
Muscatine – Emmetsburg	1 lag, intercept	30.871*** / 0.371	0.000 / 0.543
W. Burlington – Cedar Rapids	1 lag, intercept	71.720*** / 0.578	0.000 / 0.447
W. Burlington – Clinton	1 lag, intercept	60.932*** /0.498	0.000 / 0.481
W. Burlington – Davenport	1 lag, intercept	74.080*** / 0.449	0.000 / 0.503
W. Burlington – Eddyville	1 lag, intercept	107.940*** / 0.417	0.000 / 0.519
W. Burlington – Emmetsburg	1 lag, intercept	16.555** / 0.434	0.035 / 0.510
W. Burlington – Keokuk	1 lag, intercept	87.728*** / 0.426	0.000 / 0.514
W. Burlington Muscatine	1 lag, intercept	69.795*** / 0.498	0.000 / 0.480
North Carolina			
Candor – Creswell	1 lag, intercept	47.900*** / 0.448	0.000 / 0.503
Candor – Statesville	1 lag, intercept	81.178*** / 0.874	0.000 / 0.350
Cofield – Candor	1 lag, intercept	32.397*** / 0.618	0.000 / 0.432
Cofield – Creswell	1 lag, intercept	53.046*** / 0.510	0.000 / 0.475
Cofield – Statesville	1 lag, intercept	57.442*** / 0.848	0.000 / 0.357
Laurinburg – Candor	1 lag, intercept	69.425*** / 0.579	0.000 / 0.450
Laurinburg – Cofield	1 lag, intercept	52.889*** / 0.686	0.000 / 0.408

Laurinburg – Creswell	4 lags, intercept	25.889*** / 0.704	0.001 / 0.401
Laurinburg – Roaring River	1 lag, intercept	50.536*** / 0.669	0.000 / 0.414
Laurinburg – Statesville	1 lag, intercept	58.590*** / 0.842	0.000 / 0.360
Roaring River – Candor	1 lag, intercept	52.491*** / 0.706	0.000 / 0.401
Roaring River – Cofield	1 lag, intercept	34.371*** / 0.665	0.000 / 0.415
Roaring River – Creswell	1 lag, intercept	79.394*** / 0.557	0.000 / 0.455
Roaring River – Statesville	1 lag, intercept	127.425*** / 0.493	0.000 / 0.483
Statesville – Creswell	1 lag, intercept	72.570*** / 0.574	0.000 / 0.449

Note: † The first number in the column refers to the hypothesis H_0: no cointegration | H_1: at least one cointegration equation. The second number in the columns refers to the hypothesis H_0: one cointegration equation | H_1: two cointegration equations.
* p<0.10, ** p<0.05, *** p<0.01

APPENDIX D. SUMMARY STATISTICS OF PRICE TRANSMISSION ELASTICITIES

Table D.2.2.1: Summary statistics of price transmission elasticities: Interregional analysis

Year	No. of estimated market pairs	Mean	Standard deviation	Minimum	Maximum
		Russia			
2010/11	15	0.68	0.16	0.39	0.92
2011/12	15	0.51	0.29	0.06	0.97
2012/13	15	0.80	0.11	0.60	0.98
2013/14	15	0.77	0.17	0.31	0.99
2014/15	15	0.83	0.12	0.58	0.99
2015/16	15	0.51	0.26	0.09	0.96
		USA			
2010/11	54	0.87	0.11	0.66	0.99
2011/12	54	0.79	0.08	0.61	0.96
2012/13	47	0.86	0.09	0.58	0.98
2013/14	47	0.87	0.07	0.73	1.00
2014/15	47	0.79	0.12	0.54	0.98
2015/16	47	0.73	0.15	0.31	1.03

Table D.2.2.2: Summary statistics of price transmission elasticities: Intraregional analysis

Year	No. of estimated market pairs	Mean	Standard deviation	Minimum	Maximum
		Russia			
2010/11	6	0.64	0.16	0.48	0.93
2011/12	13	0.49	0.20	0.17	0.87
2012/13	18	0.57	0.20	0.24	0.94
2013/14	21	0.68	0.18	0.30	0.94
2014/15	21	0.56	0.21	0.27	0.90
2015/16	11	0.51	0.30	0.11	0.92
		USA			
2010/11	42	0.94	0.05	0.82	1.00
2011/12	42	0.93	0.06	0.76	1.00
2012/13	42	0.89	0.06	0.75	0.99
2013/14	42	0.90	0.07	0.77	1.00
2014/15	42	0.96	0.13	0.59	1.22
2015/16	42	0.91	0.06	0.81	1.00

APPENDIX E. DESCRIPTION OF VARIABLES AND SOURCES

Market integration

Russia/USA: Parameter estimates of price transmission elasticities ($\hat{\beta}$) between markets 1 and 2 for every market pair i. Source: own estimations.

Distance

Russia: railway distance (1,000 kilometers) between markets 1 and 2; calculated as railway distance between two the most relevant railway stations. Source: JSC Russian Railways https://cargo.rzd.ru/ .

USA: road distance (1,000 kilometers) between markets 1 and 2; calculated as road distance between two cities (we selected cities, which are indicated as "locations" in the provided file of price series).

Sources: Google Map www.google.com/maps .

Export

USA: export volume (1 million tons) for regional markets 1 and 2 at the state level for interregional analysis. Original export data are given in monetary values (million $), which we divide by yearly corn price (yellow corn No. 2, price received, measured in $/bu). We convert bushel to ton equivalent by the following conversion ratio: 1 ton = 39.3680. Source: USDA Economic Research Service (USDA-ERS) and USDA Foreign Agricultural Service (USDA-FAS) for export values (million $) and USDA National Agricultural Statistics Service (USDA-NASS) for corn prices.

The data is not available at the county level for intraregional analysis. We replace export values by the indicator variable exp_i, which is equal to 1 if one price of the market pair i is observed in a market which is located in a region involved in international grain export and is equal to 0 otherwise. For the intraregional analysis, exp_i equals to 1 for all market pairs located in Iowa and 0 for all market pairs located in North Carolina.

Russia: export volume (1 million tons) for regional markets 1 and 2 aggregated at the economic region level for interregional analysis. Source: Institute for Agricultural Market Studies (IKAR).
The data is not available at the oblast level for intraregional analysis. We replace export values by the indicator variable exp_i. For Interregional analysis at the economic region level, exp_i equals to 1 for all market pairs including North Caucasus as one of the prices, and 0 otherwise. For Intraregional analysis at the oblast level, exp_i equals to 1 for all market pairs located in North Caucasus and 0 for all market pairs located in West Siberia.

Grain production
Russia: production quantity (1 million tons) of spring and winter wheat for markets 1 and 2 at the economic region level for interregional analysis and production quantity (1 million tons) of spring and winter wheat for markets 1 and 2 at the oblast level for intraregional analysis. Source: Federal State Statistics Service of Russia (Rosstat).
USA: production quantity (1 million tons) of yellow corn for markets 1 and 2 at the state level for interregional analysis and production quantity (1 million tons) of yellow corn for markets 1 and 2 at the county level for intraregional analysis. Source: USDA National Agricultural Statistics Service (USDA-NASS).

Ethanol
Russia: N/A.
USA: Fuel ethanol production, including denaturant (1 million barrels) for markets 1 and 2 at the state level for interregional analysis. The data is not available at the county level for intraregional analysis. Source: U.S. Energy Information Administration (EIA).

Hog inventories
Russia: hog inventory (1 million heads) for markets 1 and 2 at the economic region level for interregional analysis and hog inventory (10,000 heads) for markets 1 and 2 at the oblast level for intraregional analysis. Source: Federal State Statistics Service of Russia (Rosstat).

USA: hog inventory (1 million heads) for markets 1 and 2 at the state level for interregional analysis; for intraregional analysis, yearly data is not available for Iowa and North Carolina at the county level (withheld by the USDA to avoid disclosing data for individual operations), which we replace by 2012 census data on hog inventory (10,000 heads). Source: USDA National Agricultural Statistics Service (USDA-NASS) for the state level data and USDA Agricultural Census for the county level data.

Cattle inventories

Russia: cattle inventory (1 million heads) for markets 1 and 2 at the economic region level for interregional analysis and cattle inventory (10,000 heads) for markets 1 and 2 at the oblast level for intraregional analysis. Source: Federal State Statistics Service of Russia (Rosstat).

USA: cattle, including calves (1 million heads) for markets 1 and 2 at the state level for interregional analysis and cattle, including calves (10,000 heads) for markets 1 and 2 at the county level for intraregional analysis. Source: USDA National Agricultural Statistics Service (USDA-NASS).

Poultry inventories

Russia: chickens and roosters inventory (10 million heads) for markets 1 and 2 at the economic region level for interregional analysis and chickens and roosters inventory (1 million heads) for markets 1 and 2 at the oblast level for intraregional analysis. Source: Federal State Statistics Service of Russia (Rosstat).

USA: chickens, excluding broilers inventory (10 million heads) augmented by broilers inventory (available only for 2012) for markets 1 and 2 at the state level for interregional analysis; for intraregional analysis, yearly data is not available for Iowa and North Carolina at the county level (withheld by the USDA to avoid disclosing data for individual operations), which we replace by 2012 census data on chickens, including broilers inventory (1 million heads). Source: USDA National Agricultural Statistics Service (USDA-NASS) for chickens (excluding broilers) inventory and USDA 2012 Census for broilers inventory at the state level, and USDA Agricultural Census 2012 for the county level data.

Population

Russia: resident population (10 million) for markets 1 and 2 at the economic region level for interregional analysis and resident population (0.1 million) for markets 1 and 2 at the oblast level for intraregional analysis. Source: Federal State Statistics Service of Russia (Rosstat).

USA: resident population (10 million) for markets 1 and 2 at the state level for interregional analysis and resident population (0.1 million) for markets 1 and 2 at the county level for intraregional analysis. Source: US Census Bureau, Population Division.

APPENDIX F. SUMMARY STATISTICS OF PANEL DATA MODEL VARIABLES

Table F.2.2.1: Summary statistics of panel data model variables: Interregional analysis

Variable	Mean	Standard deviation	Minimum	Maximum
Russia				
Price transmission elasticity	0.68	0.23	0.06	0.99
Distance	1.92	1.03	0.53	3.98
$Export_1$	4.96	6.79	0	18.70
$Export_2$	0.60	0.76	0	3.00
Grain $production_1$	0.98	0.73	0.25	2.39
Grain $production_2$	0.60	0.20	0.25	0.89
Hog_1	2.89	0.90	1.38	5.15
Hog_2	2.24	0.90	1.38	5.15
$Cattle_1$	2.50	1.01	1.10	3.54
$Cattle_2$	2.65	0.76	0.11	3.47
$Poultry_1$	1.02	0.68	0.33	1.99
$Poultry_2$	0.48	0.15	0.33	1.99
$Population_1$	1.98	0.84	0.72	3.18
$Population_2$	1.62	0.54	0.72	3.18
Year 2010/11	0.17	0.37	0	1
Year 2011/12	0.17	0.37	0	1
Year 2012/13	0.17	0.37	0	1
Year 2013/14	0.17	0.37	0	1
Year 2014/15	0.17	0.37	0	1
Year 2015/16	0.17	0.37	0	1
USA				
Price transmission elasticity	0.82	0.12	0.31	1.03
Distance	1.47	0.79	0.22	3.29

$Export_1$	0.31	0.33	0.03	1.46
$Export_2$	4.93	3.11	0.87	12.45
$Grain_1$	0.20	0.19	0.02	0.77
$Grain_2$	3.23	1.96	1.16	6.04
$Ethanol_1$	1.81	2.44	0	2.99
$Ethanol_2$	33.50	25.94	5.89	92.07
Hog_1	0.57	0.71	0.01	2.33
Hog_2	6.05	6.28	1.19	21.30
$Cattle_1$	3.71	3.22	1.04	13.3
$Cattle_2$	3.76	1.95	0.9	6.45
$Poultry_1$	6.32	6.40	0.00	19.39
$Poultry_2$	2.51	2.68	0.09	7.48
$Population_1$	11.36	12.95	0.56	39.03
$Population_2$	4.77	3.78	0.82	12.89
Year 2010/11	0.18	0.39	0	1
Year 2011/12	0.16	0.37	0	1
Year 2012/13	0.16	0.37	0	1
Year 2013/14	0.16	0.37	0	1
Year 2014/15	0.16	0.37	0	1
Year 2015/16	0.18	0.39	0	1

Table F.2.2.2: Summary statistics of panel data model variables: Intraregional analysis

Variable	Mean	Standard deviation	Minimum	Maximum
Russia				
Price transmission elasticity	0.58	0.21	0.11	0.94
Distance	0.67	0.48	0.13	1.54
Exporter	0.27	0.44	0	1
Grain $production_1$	1.84	2.31	0.09	8.46
Grain $production_2$	2.79	2.34	0.09	8.46
Hog_1	34.7	14.0	6.50	100.1
Hog_2	45.7	17.7	6.50	100.1
$Cattle_1$	29.77	15.93	4.70	64.91
$Cattle_2$	38.91	20.61	8.0	87.40
$Poultry_1$	8.13	4.15	2.73	20.81
$Poultry_2$	7.46	4.04	2.73	20.81
$Population_1$	27.5	11.47	4.43	54.84
$Population_2$	27.18	12.45	10.44	54.94

Year 2010/11	0.07	0.25	0	1
Year 2011/12	0.20	0.40	0	1
Year 2012/13	0.23	0.43	0	1
Year 2013/14	0.23	0.43	0	1
Year 2014/15	0.12	0.33	0	1
Year 2015/16	0.20	0.40	0	1
USA				
Price transmission elasticity	0.92	0.08	0.59	1.22
Distance	0.25	0.15	0.05	0.54
Exporter	0.64	0.48	0	1
Grain production$_1$	0.35	0.23	0.03	0.94
Grain production$_2$	0.56	0.31	0.03	1.43
Hog$_1$	0.08	0.10	0.00	0.30
Hog$_2$	0.13	0.16	0.00	0.46
Cattle$_1$	2.17	1.93	0.03	7
Cattle$_2$	2..40	1.76	0.03	7
Poultry$_1$	1.71	3.21	0.00	10.83
Poultry$_2$	0.89	2.06	0.00	10.83
Population$_1$	0.52	0.44	0.22	2.20
Population$_2$	0.79	0.77	0.09	2.20
Year 2010/11	0.17	0.37	0	1
Year 2011/12	0.17	0.37	0	1
Year 2012/13	0.17	0.37	0	1
Year 2013/14	0.17	0.37	0	1
Year 2014/15	0.17	0.37	0	1
Year 2015/16	0.17	0.37	0	1

APPENDIX G. PEARSON'S PAIRWISE CORRELATION COEFFICIENTS

Table G.2.2.1: Pearson's pairwise correlation coefficients: Interregional analysis, Russia

Explanatory variables	Distance	$Export_1$	$Export_2$	Grain $production_1$	Grain $production_2$	Hog_1	Hog_2	$Population_1$	$Population_2$	$Cattle_1$	$Cattle_2$	$Poultry_1$	$Poultry_2$
Distance	1												
$Export_1$	0.13	1											
$Export_2$	−0.45	0.20	1										
Grain $production_1$	0.15	**0.92**	0.13	1									
Grain $production_2$	0.18	0.03	0.42	−0.04	1								
Hog_1	0.05	−0.27	0.22	−0.29	0.06	1							
Hog_2	−0.45	0.25	**0.52**	0.22	0.04	−0.06	1						
$Population_1$	−0.15	−0.08	0.16	−0.16	0.02	−0.15	0.24	1					
$Population_2$	0.07	0.18	−0.39	0.21	−0.45	−0.07	−0.27	−0.16	1				
$Cattle_1$	0.02	**0.61**	−0.09	**0.66**	−0.06	**−0.84**	0.16	0.07	0.14	1			
$Cattle_2$	0.25	−0.21	−0.27	−0.21	−0.11	0.10	**−0.86**	−0.22	0.34	−0.20	1		
$Poultry_1$	0.15	**0.89**	0.11	**0.93**	−0.12	−0.20	0.26	−0.12	0.20	**0.59**	−0.23	1	
$Poultry_2$	−0.41	0.17	0.31	0.15	−0.23	0.03	**0.66**	0.19	−0.23	0.06	**−0.52**	0.13	1

Note: values higher than |0.50| are marked in bold.

Table G.2.2.2: Pearson's pairwise correlation coefficients: Interregional analysis, USA

Explanatory variables	Distance	$Export_1$	$Export_2$	Grain $prod._1$	Grain $prod._2$	$Ethanol_1$	$Ethanol_2$	Hog_1	Hog_2	$Population_1$	$Population_2$	$Cattle_1$	$Cattle_2$	$Poultry_1$	$Poultry_2$
Distance	1														
$Export_1$	−0.33	1													
$Export_2$	0.15	0.12	1												
Grain $prod._1$	−0.35	**0.93**	0.02	1											
Grain $prod._2$	0.15	0.05	**0.88**	0.05	1										
$Ethanol_1$	0.16	**0.64**	0.06	**0.64**	0.05	1									
$Ethanol_2$	0.12	0.03	**0.73**	0.02	**0.79**	0.03	1								
Hog_1	−0.34	0.08	0.00	0.09	0.00	−0.04	0.01	1							
Hog_2	0.15	0.02	**0.61**	0.02	**0.69**	0.02	**0.88**	0.01	1						
$Population_1$	**0.63**	0.15	0.02	0.15	0.03	**0.81**	0.03	−0.20	0.01	1					
$Population_2$	0.09	0.04	0.33	0.04	0.44	0.06	0.01	0.00	−0.04	0.02	1				
$Cattle_1$	−0.01	**0.58**	0.03	**0.60**	0.06	0.15	0.01	0.32	0.02	**0.63**	0.04	1			
$Cattle_2$	−0.21	0.06	−0.31	0.06	−0.35	0.04	0.46	0.01	−0.20	0.03	**−0.70**	0.07	1		
$Poultry_1$	−0.18	0.39	0.01	0.40	0.02	**0.73**	0.01	−0.13	0.01	0.17	0.02	0.30	0.03	1	
$Poultry_2$	0.06	0.04	0.16	0.04	0.23	0.04	−0.17	0.01	**0.69**	0.02	−0.05	0.05	−0.04	0.02	1

Note: Values higher than |0.50| are marked in bold.

Table G.2.2.3: Pearson's pairwise correlation coefficients: Intraregional analysis, Russia

Explanatory variables	Distance	Exporter	Grain production$_1$	Grain production$_2$	Hog$_1$	Hog$_2$	Population$_1$	Population$_2$	Cattle$_1$	Cattle$_2$	Poultry$_1$	Poultry$_2$
Distance	1											
Exporter	−0.48	1										
Grain production$_1$	−0.34	**0.75**	1									
Grain production$_2$	−0.47	**0.90**	**0.71**	1								
Hog$_1$	0.13	−0.21	0.23	−0.25	1							
Hog$_2$	0.02	−0.16	0.06	0.09	0.19	1						
Population$_1$	0.24	0.05	0.47	−0.07	**0.60**	−0.01	1					
Population$_2$	−0.39	**0.87**	**0.69**	**0.88**	−0.17	0.10	0.03	1				
Cattle$_1$	−0.17	0.20	**0.63**	0.14	**0.57**	0.11	**0.63**	0.16	1			
Cattle$_2$	−0.41	**0.56**	0.44	**0.63**	−0.06	0.27	0.06	**0.67**	0.04	1		
Poultry$_1$	−0.22	**0.60**	**0.88**	0.48	0.32	−0.03	**0.72**	**0.53**	**0.73**	0.35	1	
Poultry$_2$	−0.34	**0.64**	0.39	**0.68**	−0.18	0.11	−0.17	**0.79**	−0.02	0.45	0.23	1

Note: values higher than |0.50| are marked in bold.

Table G.2.2.4: Pearson's pairwise correlation coefficients: Intraregional analysis, USA

Explanatory variables	Distance	Exporter	Grain production$_1$	Grain production$_2$	Hog$_1$	Hog$_2$	Population$_1$	Population$_2$	Cattle$_1$	Cattle$_2$	Poultry$_1$	Poultry$_2$
Distance	1											
Exporter	−0.15	1										
Grain production$_1$	−0.06	**0.64**	1									
Grain production$_2$	0.43	0.20	0.18	1								
Hog$_1$	−0.02	**0.56**	0.48	0.11	1							
Hog$_2$	0.46	**0.60**	0.42	0.30	0.28	1						
Population$_1$	0.22	0.03	0.17	0.22	−0.06	0.25	1					
Population$_2$	**−0.51**	0.17	0.14	−0.18	0.12	−0.26	−0.09	1				
Cattle$_1$	−0.02	0.08	−0.21	−0.07	0.01	0.03	−0.10	0.00	1			
Cattle$_2$	−0.01	0.15	0.33	0.01	0.18	0.12	0.13	0.07	−0.05	1		
Poultry$_1$	0.06	**−0.72**	**−0.50**	−0.18	−0.40	−0.43	0.07	−0.12	−0.09	−0.12	1	
Poultry$_2$	−0.04	**−0.58**	−0.38	**−0.57**	−0.33	−0.34	−0.10	−0.06	−0.05	−0.08	0.35	1

Note: Values higher than |0.50| are marked in bold.

APPENDIX H. VARIANCE INFLATION FACTORS (VIF)

Table H.2.2.1: Variance Inflation Factors: Interregional analysis

	Russia						
Explanatory variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Distance	1.5	1.1	1.3	1.1	1.3	1.0	3.3
$Export_1$	1.2						**9.1**
$Export_2$	1.8						**9.1**
Grain $production_1$		1.1					**23.1**
Grain $production_2$		1.6					4.5
$Ethanol_1$							
$Ethanol_2$							
Hog_1			1.1				**10.3**
Hog_2			1.3				**19.6**
$Cattle_1$				1.1			**15.0**
$Cattle_2$				1.1			**11.5**
$Poultry_1$					1.1		**15.0**
$Poultry_2$					1.3		4.6
$Population_1$						1.0	1.4
$Population_2$						1.1	3.8
Year dummies	yes	yes	yes	yes	yes	yes	yes
Mean VIF	1.6	1.6	1.5	1.5	1.5	1.4	**8.0**

Note: VIF > 5 suggests multicollinearity is high; values higher than 5 are marked in bold.

	USA							
	(1)	(2)	(2′)	(3)	(4)	(5)	(6)	(7)
	1.2	1.2	1.1	1.2	1.1	1.0	1.7	4.7
	1.2							**16.9**
	1.2							**15.0**
		1.2						**16.0**
		1.0						**135.7**
			1.1					**13.4**
			1.0					**137.5**
				1.1				2.4
				1.0				**13.6**
					1.0			**8.9**
					1.1			3.7
						1.0		2.4
						1.0		**5.4**
							1.7	**11.9**
							1.0	**52.4**
	yes	yes	yes	yes	yes	yes	yes	yes
	1.5	1.4	1.4	1.4	1.4	1.4	1.6	**22.6**

Table H.2.2.2: Variance Inflation Factors: Intraregional analysis

	Russia						
Explanatory variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Distance	1.3	1.3	1.0	1.3	1.2	1.3	2.1
Exporter	1.4						**15.9**
Grain production$_1$		2.2					**12.0**
Grain production$_2$		2.5					**13.4**
Hog$_1$			1.1				2.7
Hog$_2$			1.1				2.3
Cattle$_1$				1.1			4.2
Cattle$_2$				1.2			2.8
Poultry$_1$					1.1		**15.9**
Poultry$_2$					1.2		3.5
Population$_1$						1.1	**7.0**
Population$_2$						1.2	**10.7**
Year dummies	yes	yes	yes	yes	yes	yes	yes
Mean VIF	1.7	1.9	1.5	1.6	1.6	1.6	**6.1**

Note: VIF > 5 suggests multicollinearity is high; values higher than 5 are marked in bold.

	USA						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	1.0	1.3	1.3	1.0	1.0	1.4	2.7
	1.0						**6.3**
		1.1					2.4
		1.3					2.2
			1.1				1.6
			1.4				3.5
				3.0			3.4
				1.2			1.4
					1.2		2.2
					1.2		2.5
						1.1	1.2
						1.3	1.4
	yes	yes	yes	yes	yes	yes	yes
	1.5	1.5	1.5	2.1	1.5	1.5	2.5

3 THE INFLUENCE OF THE 2010/11 EXPORT BAN ON SPATIAL MARKET EFFICIENCY OF GRAIN MARKETS IN RUSSIA

3.1 THE INFLUENCE OF THE 2010/11 EXPORT BAN ON SPATIAL MARKET EFFICIENCY OF GRAIN MARKETS IN RUSSIA

Earlier versions of this paper were presented as:

- Contributed Paper at the 57th Annual Conference of the German Association of Agricultural Economists (GeWiSoLa) "Bridging the Gap between Resource Efficiency and Society's Expectations in the Agricultural and Food Economy", September 13–15, 2017, Munich, Germany.
- Contributed Paper at the XV EAAE Congress "Towards Sustainable Agri-Food Systems: Balancing between Markets and Society", August 29–September 1, 2017, Parma, Italy.
- Contributed Paper at the AAEA Annual Meeting, July 30–August 1, 2017, Chicago, USA.
- Contributed Paper at the IAMO-Forum 2017 "Eurasian Food Economy between Globalization and Geopolitics", June 21–23, 2017, Halle (Saale), Germany.

Study outcomes also constitute a part of the World Bank report:

- World Bank (2018). Europe and Central Asia – The impacts of the El Niño and La Niña on large grain producing countries in ECA: yield, poverty and policy response. Washington, D.C.: World Bank Group.

The influence of the 2010/11 export ban on spatial market efficiency of grain markets in Russia

Abstract

Empirical evaluation of the effects of the 2010/11 wheat export ban on domestic price relationships in Russia within a price transmission analysis shows that regional wheat market integration significantly increased in Russia during the period of export restrictions. We attribute this to the increased influence of common domestic factors on price formation and increased interregional trade flows. Using a TVECM, we find that Russian wheat markets were also characterized by higher transaction costs during the export ban period, resulting from increased uncertainty and market risk. Investments in transport infrastructure and storage facilities may improve the regional connectivity and cushion potential production shocks. However, export restrictions increase market instability, which discourages investments in grain production and hence, has a detrimental effect on the development of grain market infrastructure.

Keywords: export ban, wheat, Russia, regional market integration, TVECM

1 Introduction

During the 2007/08 and 2010/11 food price spikes 33 countries in total applied 87 food export restricting measures (FAO, 2011). Export restrictions implemented by the major trading countries not only contributed to increasing the world price levels and volatility of the staple crops (Martin and Anderson, 2011; Rude and An, 2015), but they also resulted in significant welfare losses for developing, net import-dependent countries and export restricting countries (Yu et al., 2011; Mitra and Josling, 2009).

Unusually low harvest in Russia's key crop growing areas in 2010 also prompted the Russian government to impose a wheat export ban on August 15, 2010. Initially, the ban was introduced to last until December 2010, but it was subsequently prolonged until July 2011. The export ban aimed to decrease domestic prices and maintain adequate availability of grain within Russia.

This study aims to shed light on the domestic price effects of export restrictions by examining the effects of the 2010/11 wheat export ban on domestic price relationships in Russia. We address the research question within a price transmission framework and compare the spatial integration of wheat markets in Russia during the export ban period (2010/11) vis-à-vis the open trade regime (2009/10). We are not aware of any existing study which has investigated the export restrictions' effects on domestic price relationships.

Contrasting, the effects of Russia's wheat export restrictions on the domestic price level have been investigated in the literature before. Götz et al. (2013) find a rather low price dampening effect of the 2007/08 export tax in Russia during the global food price crisis, whereas results of Götz et al. (2016) suggest a strong regional variation in the price dampening effects of the 2010/11 wheat export ban, varying between 35% and 67%. While those studies focus on the relationship between the world market price and Russian wheat market prices, this study differs, as it investigates the influence of the 2010/11 export ban on domestic price relationships solely between the grain producing regions of Russia.

Since variation in wheat production is rather high in Russia, strong market integration (i.e., full and active transmission of price information between regional markets) is required to induce respective trade flows, smooth out grain availability, and stabilize prices within the country, especially during extreme weather events. As the spatial trade arbitrage theory (Goodwin and Piggott, 2001) postulates, trade arbitrage between two spatially separated markets will take place if the price difference exceeds transaction costs (we use "transaction costs" and "trade costs" interchangeably, which may include measurable costs, such as transportation and marketing costs, as well as unmeasurable costs, such as contract default risk, bargaining, search, and information costs). The presence of high transaction costs contradicts conditions of an efficiently functioning market, which is characterized by low search costs and easy access to information (Aker, 2010). Therefore, taking trade costs into account is essential in the context of spatial price transmission analysis.

Trade costs are particularly relevant for the analysis of the Russian wheat market, which is characterized by regional trade over long distances of up to 4,000 kilometers. We use a Threshold Vector Error Correction Model (TVECM) to explicitly account for the influence of trade costs on spatial price relationships and employ an advanced regularized Bayesian estimator, as suggested by Greb et al. (2014). Hence, a further novelty of our approach is that, by using a TVECM, we also assess the potential effects of the export ban on transaction costs. In this regard, we complement Svanidze and Götz (2019), which based on a TVECM investigate regional integration of the wheat market in Russia in comparison to the USA, focusing on the period when exports to the world market were freely possible.

We structure the remainder of this paper as follows: We discuss Russian wheat market characteristics, regional trade, and the export ban of 2010/11 in section 2 and provide a methodological framework and estimation strategy in section 3. Section 4 describes the price data and their time series properties. In sections 5, we present the estimation results, which are discussed in section 6 together with concluding remarks.

2 Russian wheat market characteristics and the 2010/11 export ban

Wheat production in Russia is mainly concentrated in six economic regions (Fig. 3.1.1). Black Earth, North Caucasus, Volga, Ural, and West Siberia usually supply their excess grain production to other regional markets or export it to the international markets, whereas the Central region with Moscow is the primary wheat deficit region, depending heavily on external supply.

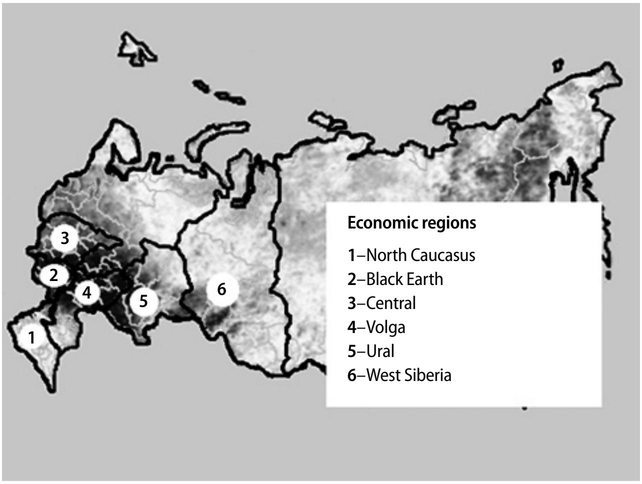

Fig. 3.1.1: Map of crop-growing regions affected by drought in 2010

Note: Temperature anomalies for the Russian Federation from July 20 to 27, 2010 relative to temperatures for the same period in the years 2000–2008. Darker hue depicts areas with above-average temperature anomalies compared to those with below-average temperatures (lighter hue).

Source: Adapted from Wegren (2011), own elaborations

Table 3.1.1: Wheat production (million t) and exports (as a % of production), 2009–2015

Year	Total Russia	North Caucasus	West Siberia	Volga	Black Earth	Ural	Central
2009	61.8 (30%)	17.9 (-)	11.3 (-)	10.1 (-)	7.9 (-)	5.7 (-)	4.0 (-)
2010	41.5 (10%)	18.6 (15%)	8.1 (0%)	3.4 (10%)	3.3 (2%)	2.5 (0%)	2.6 (0%)
2011	56.2 (38%)	20.7 (86%)	8.8 (3%)	6.8 (14%)	5.7 (21%)	7.2 (13%)	2.6 (6%)
2012	37.7 (30%)	12.9 (68%)	4.4 (5%)	5.7 (7%)	5.4 (21%)	3.1 (6%)	3.0 (5%)
2013	52.1 (36%)	17.8 (79%)	8.0 (4%)	7.2 (21%)	7.8 (23%)	4.0 (4%)	3.8 (5%)
2014	59.1 (39%)	22.4 (77%)	6.8 (1%)	8.9 (27%)	8.3 (24%)	4.5 (5%)	4.0 (4%)
2015	61.0 (42%)	23.9 (79%)	8.0 (3%)	7.4 (30%)	7.6 (40%)	5.5 (6%)	4.4 (8%)

Note: The hyphen (-) indicates that data is not available.
Source: Rosstat (2018) for production and IKAR (2018) for export data

In Table 3.1.1, we provide wheat production and export statistics at the regional level in Russia from 2009–2015. North Caucasus is the primary production and export region, accounting for almost 50% of Russia's total wheat production and 80% of total wheat exports. Since North Caucasus supplies wheat primarily to the world markets, its role in domestic trade is limited. During 2009–2015, wheat production in North Caucasus increased from 18 to 24 million tons, of which 70–80% on average was exported yearly to the world market (with the exception of the 2010 marketing year). In contrast, West Siberia, which is one of the largest grain producing regions, exports only 1%–5% of its total wheat production to the world markets. Located 4,000 kilometers away from the Black Sea ports, West Siberia has limited access to the country's main export gateways, and thus its role in the global wheat supply is rather restricted. West Siberia is far away not only from the world market, but also the main grain consumption regions within Russia. In particular, Moscow is about 2,000–3,000 kilometers away. Wheat produced in West Siberia is mainly consumed within the region or delivered to the neighboring region Ural.

Weather conditions strongly influence grain production in Russia, resulting in large temporary variations across regions and years. For instance, compared to the average wheat production from 2009–2015, total wheat production decreased by 21% and 29%, respectively, in 2010 and 2012, when a critical drought hit wheat-producing regions in Russia.

Variation in wheat production is also remarkably high at the regional level in Russia. In the 2010 drought year, wheat production decreased in the regions of Central, Black Earth, Ural, Volga, and West Siberia, whereas wheat production increased by 4% in North Caucasus. Similarly, in 2014 and 2015, which had above-average wheat harvest overall, wheat production was 15% lower in West Siberia (in 2014) and 17% and 8% lower in the Volga and Black Earth (in 2015) regions.

Unusually low harvest in the key crop growing areas in 2010 led the Russian government to impose a wheat export ban on August 15th. The measure had a profound effect on regional wheat trade in Russia. North Caucasus especially, where drought did not hit wheat crops in 2010, could no longer export wheat to the world market and was forced to supply wheat domestically instead. North Caucasus directed its flows to markets that suffered the most from harvest failure, specifically Central, Black Earth, Ural, and Volga. West Siberia was also less severely affected by the drought and supplied wheat to the domestic grain producing regions, which turned into deficit regions in 2010; in particular, Ural and Volga.

To foster interregional grain trade during the export ban, the Russian government introduced railway tariff subsidies for grain producers located in North Caucasus starting on September 20th, 2010. The subsidy was valid for all grain supplies exceeding 300 kilometers and was removed when the export ban was lifted in July 2011. Russian Railways cut delivery fees by half for dispatches heading from North Caucasus towards the regions of Black Earth, Central, Ural, and Volga. However, delivery fees capture just parts of the full transport costs. Other expenses may include storage fees, transportation to and from the railway stations and grain processing facilities, loading and unloading costs, insurance premiums, etc. The share of the delivery fee in the total transport costs may vary significantly, amounting to 30% to 70% of transport costs.

As production areas cover large territories, the influence of transport infrastructure is crucial on the distribution of wheat within Russia. The quality of transport infrastructure strongly differs between regions. The density of the railway network is the highest in the European part of Russia, whereas it is much lower in Ural and West Siberia. In addition, grain traders regularly complain that the number of grain wagons in the peak seasons does not suffice (Gonenko, 2011). During the 2010/11 export ban, the availability of wagons for grain transportation was limited as railways were heavily involved in the construction of sports facilities for the winter Olympic games in Sochi. Moreover, trade flows reversed, and the volume of grain exported by North Caucasus to other domestic regions was extremely high, even exceeding the availability of trucks (Gonenko, 2011). Grain markets in Russia are also characterized by inadequate transport infrastructure and logistics and high business risk (PWC, 2015). Trade costs are especially high due to the difficulty of enforcing contracts and unforeseen policy interventions on grain markets (Götz et al., 2016, 2013).

3 Methodological framework and estimation strategy

Highly integrated markets characterized by strong price relationships and fast transmission of price changes between spatially separated regions are usually interpreted as spatially efficient markets (Fackler and Goodwin, 2001). Market integration is characterized by long-run price equilibrium and short-run price adjustment, i.e., correction of price disequilibrium.

We characterize the long-run price equilibrium between spatially separated markets by the equation

$$p_{1t} = \alpha + \beta p_{2t} + \varepsilon_t \tag{1}$$

where p_{1t} and p_{2t} are domestic prices at the regional markets 1 and 2 expressed in the natural logarithm and represents the stationary disturbance term. α denotes the intercept and β is a coefficient of the long-run price transmission elasticity, characterizing the magnitude of the transmission of price shocks from one market to another. The equation (1) is built on the implicit assumption that trade costs are stationary over time. Otherwise, it would not be possible to correctly identify a long-run price equilibrium (Fackler and Goodwin, 2001).

Long-run equilibrium is a static notion. It is natural that prices in different markets periodically diverge from this parity owing to unexpected market shocks. According to the spatial trade arbitrage theory (Goodwin and Piggott, 2001), trade arbitrage between two spatially separated markets will take place if the price difference exceeds transaction costs.

Thus, a "regime dependent" price adjustment process may be observed, which we examine using the non-linear three-regime TVECM with 2 thresholds (Greb et al., 2013) to also account for the influence of trade costs that are highly relevant to the Russian wheat market. In the following TVECM model

$$\Delta \boldsymbol{p_t} = \begin{cases} \boldsymbol{\rho}_1 \varepsilon_{t-1} + \sum_{m=1}^{M} \boldsymbol{\Theta}_{1m} \Delta \boldsymbol{p}_{t-m} + \boldsymbol{\omega}_{1t}, & if \quad \varepsilon_{t-1} \leq \tau_1 \quad (Lower) \\ \boldsymbol{\rho}_2 \varepsilon_{t-1} + \sum_{m=1}^{M} \boldsymbol{\Theta}_{2m} \Delta \boldsymbol{p}_{t-m} + \boldsymbol{\omega}_{2t}, & if \quad \tau_1 < \varepsilon_{t-1} \leq \tau_2 \ (Middle) \\ \boldsymbol{\rho}_3 \varepsilon_{t-1} + \sum_{m=1}^{M} \boldsymbol{\Theta}_{3m} \Delta \boldsymbol{p}_{t-m} + \boldsymbol{\omega}_{3t}, & if \quad \tau_2 < \varepsilon_{t-1} \quad (Upper) \end{cases} \quad (2)$$

$\Delta \boldsymbol{p}_t = (\Delta p_{1t}, \ \Delta p_{2t})$ denotes the vector of price changes, i.e. the difference between prices in periods t and $t-1$ for both markets in question. Error correction terms ε_{t-1}, lagged residuals from equation (1), represent the price deviation from the long-run price equilibrium. It also serves as a threshold variable τ, which determines the state of the regime r, $r = 1,2,3$, 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 ($\boldsymbol{\rho}_r$) and the coefficients of the price differences ($\boldsymbol{\Theta}_{rm}$) for each regime r, $r = 1,2,3$. Lagged price variables $\Delta \boldsymbol{p}_{t-m}$ are introduced to correct residual correlation up to the period M. $\boldsymbol{\omega}_t$ denotes a white-noise process with expected value $E(\boldsymbol{\omega}_t) = \boldsymbol{0}$ and covariance matrix $Cov(\boldsymbol{\omega}_t) = \boldsymbol{\Omega} \in (\mathbb{R}^{+})^{2\times 2}$.

The adjustment parameter $\boldsymbol{\rho_r} = (\rho_{1r}, \ \rho_{2r})$, with the expected value of $\rho_{1r} \leq 0$ and $\rho_{2r} \geq 0$ measures how quickly deviations from the long-run equilibrium are eliminated. A smooth convergence to equilibrium is achieved by satisfying the condition $0 < \rho_{2r} - \rho_{1r} < 1$ (Greb et al., 2014). The total speed of adjustment (equal to $\rho_{2r} - \rho_{1r}$) may differ between the regimes. In the upper and lower regimes, the speed of adjustment is faster due to the profitable trade arbitrage opportunities. However, we expect that price adjustment does not occur in the middle regime as price deviations are smaller than the threshold values; or if it does, for example via information flows or third markets, then the speed of adjustment coefficients are lower in the middle regime (Stephens et al., 2012).

The three-regime TVECM assumes that two thresholds (τ_1 and τ_2) exist corresponding to the costs of trade in both directions, i.e., from one market to the other and vice versa. Restrictions are imposed on threshold values such that $\tau_1 < 0 < \tau_2$ captures the trade reversals. To identify optimal thresholds, we apply a novel regularized Bayesian estimator (Greb et al., 2014), which in contrast to the traditional estimators (Chan, 1993;

Hansen and Seo, 2002) the regularized Bayesian estimator ensures that thresholds are well defined on the entire space of threshold parameters, with substantial outperformance in small samples (Greb et al., 2014).

To evaluate the spatial price linkages between markets, we proceed as follows. First, we test the order of integration of each price series by the Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1981). Second, we determine the existence of long-run price equilibrium by applying tests of threshold cointegration (Hansen and Seo, 2002; Larsen, 2012). Next, if the tests suggest cointegration between a pair of individually nonstationary price series, we estimate the long-run price equilibrium in equation (1) using the ordinary least squares method. This is followed by TVECM estimations first by identifying the thresholds (Greb et al., 2014) and then estimating other model parameters within the restricted maximum likelihood framework.

4 Price series, unit root, and cointegration

We use a unique dataset of weekly wheat prices (Ruble/ton) for the six primary grain producing regions of Central, Black Earth, North Caucasus, Ural, Volga, and West Siberia. The data was collected by the Russian Grain Union and is not publicly available. The quoted prices are paid by traders to farmers on the basis of ex-works contracts.

However, due to the weather conditions, regional wheat harvest in Russia is highly volatile. This results in the changing direction and size of trade flows between regions, causing oscillating price developments. In particular, the price in North Caucasus is in some years higher and in other years lower than prices in, for example, Volga and West Siberia (Fig. 3.1.2).

This implies that the interregional price relationships, which are depicted in the price transmission model, are not stable, and thus parameter estimates may not be constant. We suspect that the data generating process differs from one marketing year to another. This requires the price transmission model for Russia to be estimated based on one marketing

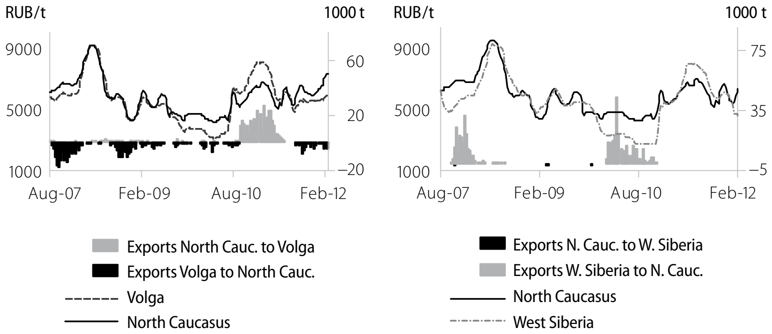

Fig. 3.1.2: Wheat prices and regional trade by railway in Russia: North Caucasus and Volga (left), North Caucasus and West Siberia (right)

Source: Reproduced from Götz et al. (2016)

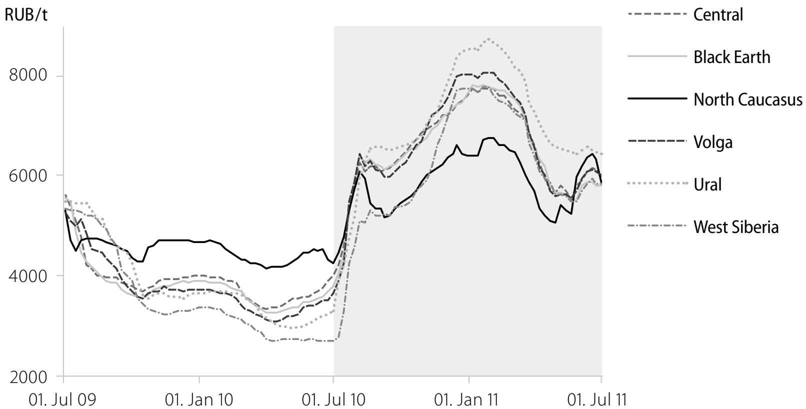

Fig. 3.1.3: Development of regional wheat prices in Russia during 2009–2011

Source: Russian Grain Union (2015)

year only, which is characterized by relatively stable price relationships (Svanidze and Götz, 2019).

Therefore, to evaluate the effect of the export ban on domestic price relationships, we confine our analysis to price data for the individual grain producing regions for the 2009/10 marketing year only (when the trade was freely possible) as a benchmark against which price relationships during the 2010/11 export ban are evaluated. We construct two independent datasets for 2009/10 and 2010/11, each comprising 15 regional price pairs generated by price series with 52 weekly observations between July and June of a marketing year (Fig. 3.1.3).

Results of the ADF-test suggest that all price series of our database are nonstationary, i.e. they are integrated of order one (Table A.3.1.1, Appendix). Results of the threshold cointegration tests suggest that the null hypothesis of linear cointegration is rejected against a threshold cointegration at the 10% level of significance for all price pairs during the free trade regime of 2009/10 and the export ban of 2010/11 (Table A.3.1.2, Appendix). Therefore, price relationships within the Russian wheat market are characterized by a long-run spatial price equilibrium and may be modelled within the TVECM.

5 Empirical results

In this section, we discuss the estimation results of the price transmission analysis for the Russian wheat market in the 2009/10 marketing year, when the trade was freely possible, and the 2010/11 marketing year, when Russian government imposed the export ban.

5.1 The long-run price equilibrium

As Fig. 3.1.4 shows, individual estimates of the long-run price transmission elasticities for 2009/10 are widely dispersed across market pairs, indicating that wheat market integration in Russia is characterized by a heterogeneous structure ranging from almost fully integrated to nearly segregated markets. The long-run price transmission elasticity is especially the strongest between the neighboring regions Central and Black Earth (0.94), the first of which is the major consumption center and the second a large production region. The lowest long-run price transmission elasticity is observed between North Caucasus and West Siberia (0.13), two grain production regions that are the furthest from each other.

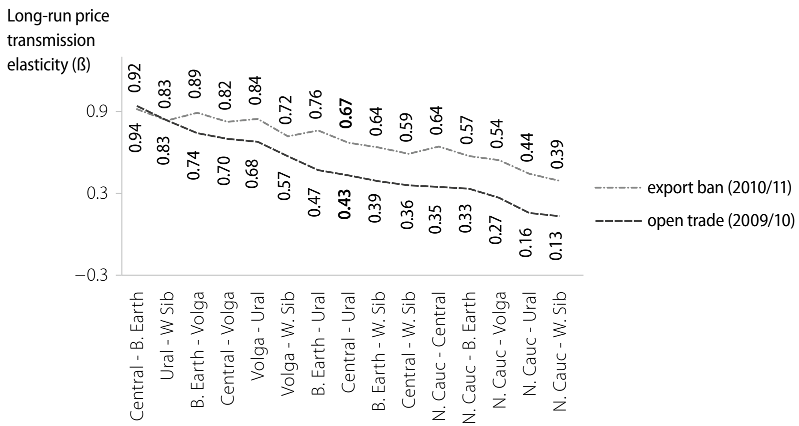

Fig. 3.1.4: The parameters of the long-run price transmission elasticities, 2009/10 and 2010/11

Note: Price pairs on the x-axis are sorted based on the values of price transmission elasticities in 2009/10 in a descending order (from left to right). Median is indicated in bold.

The median wheat price transmission elasticity is equal to 0.43 during the open trade regime of 2009/10. However, in the 2010/11 marketing year, when several production regions experienced severe drought and exports to the world market were forbidden under the export ban, the median price transmission elasticity increased to 0.67, which corresponds to a 56% increase compared to the open trade regime. Furthermore, during the export ban period, the slope coefficient increases for 13 out of the 15 price pairs compared to 2009/10. All price pairs involving North

Caucasus report the largest percentage increases in the long-run price transmission elasticities, varying between about 70% and 200%, whereas for other price pairs this change ranges from −2% to 65%.

Furthermore, we use the Wald test to assess whether the coefficients of long-run price transmission elasticities are statistically different between the free trade and export ban regimes. We follow Götz et al. (2016) in our testing procedure and estimate model (1) for 2009–2011, in which model variables are interacted with a dummy variable to account for the period with export restrictions. We apply heteroscedasticity and autocorrelation consistent (HAC) covariance estimator to correct estimated standard errors for the accompanying autocorrelation and heteroscedasticity (Newey and West, 1987).

Table A.3.1.3 in Appendix reports Wald test statistics for the effects of the export ban on price-transmission elasticities compared to the free trade regime. In 11 of 15 price pairs, the test indicates that the price transmission elasticities during the export ban period differ statistically from the values observed during the free trade regime. In contrast, long-run price transmission elasticities for price pairs Central-Black Earth, Central-Volga, Black Earth-Volga and Ural-West Siberia are unable to be differentiated between the regimes. The results of the Wald test for these four price pairs may be explained by the direction of trade flows, as we do not observe trade reversal for these price pairs during the export ban.

Motivated by the results of the Wald test, we estimate TVECM separately for the free trade and export ban periods.

5.2 Estimated parameters of the TVECM

Selected parameters of the 3-regime TVECM, which is estimated for the 15 market pairs separately for the 2009/10 and 2010/11 marketing years, are presented in Tables A.3.1.3 and A.3.1.4 in the Appendix, respectively. Based on these parameter estimates, we construct boxplots, which are shown in Fig. 3.1.5 and Fig. 3.1.6.

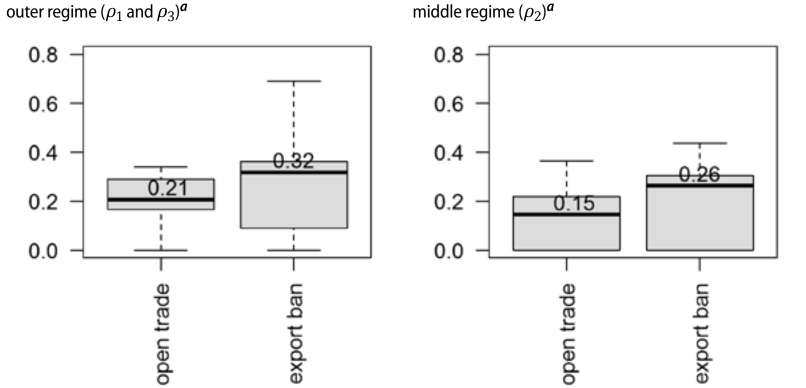

Fig. 3.1.5: Boxplots of the estimated total speed of adjustment parameters, 2009/10 and 2010/11

Note: [a] The total speed of adjustment in the outer regimes is calculated as the average of parameter estimates in the upper and lower regimes. Statistically insignificant values of at least 10% are replaced by zeros. Plots are based on estimated parameters given in Tables A.3.1.4 and A.3.1.5 in Appendix.

5.2.1 Correction of temporary price disequilibrium

We plot the total speed of adjustment parameters in Fig. 3.1.5 for the outer (upper and lower regimes) and middle regimes based on individual parameters provided in Tables A.3.1.3 and A.3.1.4 in the Appendix.

The results conform to our theoretical expectations, indicating that the total speed of adjustment is generally higher in the outer regime than in the middle regime. The median speed of the adjustment parameter during the open trade (export ban) period equals 0.21 (0.32) in the outer regime, whereas the median estimate in the middle regime amounts to 0.15 (0.26). Also, lower incidences of price adjustment are observed in the middle compared to the outer regime. We find six price pairs without price adjustment in the middle regime, while just one price pair in the outer regime for 2009/10. Similarly, we identify five price pairs in the middle and three price pairs in the outer regimes without significant price adjustment in 2010/11.

Among the 15 price pairs in 2009/10, the total speed of the adjustment parameter is the highest for the neighboring regions Central-Black Earth, as 34% and 73% of the price disequilibrium is corrected each week in the lower and upper regimes, respectively. The size of the total speed of adjustment decreases to 17% and 31% for the price pairs Central-Ural and 17% and 26% for the price pairs Central-West Siberia, in the lower and upper regimes, respectively, reflecting the negative influence of distance. Similar to the long-run price equilibrium analysis, price pairs involving North Caucasus typically report the lower speed of adjustment parameters compared to the price pairs without North Caucasus. For price pairs that include North Caucasus, the highest speed of adjustment parameter in the outer regime is observed for the North Caucasus-Central price pair, amounting to a 30% price disequilibrium correction in a week. For others, the price adjustment is either slower (North Caucasus-Black Earth, North Caucasus-Volga, North Caucasus-West Siberia) or does not occur (North Caucasus-Ural).

The median speed of adjustment in the outer regime increases from 0.21 in 2009/10 to 0.31 in 2010/11, corresponding to an improvement in the speed of price adjustment of almost 50% during the export ban period (Fig. 3.1.5). However, this improvement in the correction of price disequilibrium could not be generalized to the entire sample of price pairs. For example, during the export ban period, prices stopped adjusting in the outer regime for price pairs North Caucasus-Central, North Caucasus-Volga, and Black Earth-Ural.

5.2.2 Transaction costs

In Fig. 3.1.6, we separately plot lower (τ_1) and upper (τ_2) thresholds corresponding to transaction costs in reversed and regular trade directions, respectively. Regardless of the state of trade openness, transaction costs are usually lower in regular trade routes than in reverse directions. Specifically, the median upper threshold is 1.5 and 2.5 times lower compared to the lower threshold in 2009/10 and 2010/11, respectively.

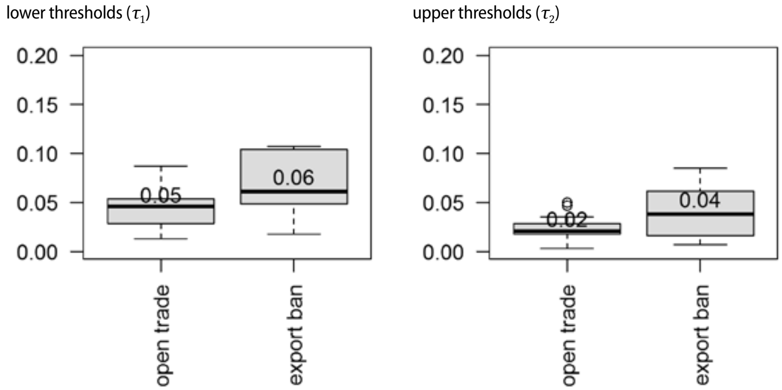

Fig. 3.1.6: Boxplots of the estimated threshold parameters, 2009/10 and 2010/11

Note: Absolute values of the threshold estimates are plotted on the graphs. Plots are based on estimated parameters given in Tables A.3.1.4 and A.3.1.5 in the Appendix.

Turning to the individual estimates given in Tables A.3.1.3 and A.3.1.4 in the Appendix, the upper threshold values (τ_2) are smaller than the lower thresholds (τ_1) for all price pairs but Black Earth-Ural (2009/10) and North Caucasus-West Siberia (2010/11). For the price pair Black Earth-Ural, however, the regular trade direction is from Black Earth to Ural ($\tau_1 = 0.039$) rather than from Ural to Black Earth ($\tau_2 = 0.05$) . Concerning the price pair North Caucasus-West Siberia, wheat was regularly delivered from West Siberia to North Caucasus for further export during the free trade regime, which corresponds to the upper threshold (τ_2) of size 0.027 in 2009/10. However, during the export ban, the upper threshold increases by almost three times to a value of 0.075, possibly because West Siberia, which similarly to North Caucasus did not experience severe harvest shortfalls in 2010/11, did not receive railway tariff subsidies from the government, whereas the Russian Railways cut delivery fees by half for dispatches heading from North Caucasus towards the regions of Black Earth, Central, Ural, and Volga. This distribution scheme of railway subsidies created less advantageous conditions for wheat deliveries from West Siberia, not only in the direction of North Caucasus but also other regions.

The thresholds increase significantly during the export ban period, implying that interregional trade costs also increased in 2010/11 (Fig. 3.1.6). The median upper threshold is about two times higher in 2010/11 (0.04) than in 2009/10 (0.02) and the median lower threshold also increases by 50% during the export ban (0.06) compared to the free trade regime (0.05).

Interestingly, all price pairs that include Ural or West Siberia as a region are characterized by relatively large thresholds in both the restricted and open trade regimes, which can be explained by the peripheral location of these regions and the high transaction costs involved. Individual estimates of upper thresholds (τ_2) during the open trade regime indicate that transaction costs for price pairs including Ural and West Siberia vary between 0.02 and 0.05, whereas, for other price pairs, they range from 0.003 to 0.02. During the export ban period, thresholds are again generally higher for price pairs including Ural and West Siberia (0.031–0.085) compared to other price pairs (0.007–0.038). On the other hand, thresholds are rather low for the price pair Ural-West Siberia, which are neighboring regions characterized by strong integration. Particularly, for this price pair, the upper threshold is equal to 0.01 in 2009/10 and 0.03 in 2010/11.

6 Discussion of results and conclusions

We have investigated the influence of the export ban on Russian wheat price relationships. The results of this price transmission analysis have made evident that during the period of export restriction, the transmission of price changes strengthened, the correction of deviations from price equilibrium accelerated, and transaction costs increased within the domestic grain market in Russia compared to the open trade regime.

Using a TVECM approach to analyze spatial price relationships in the wheat market of Russia we find more price pairs correcting price disequilibrium (and more rapidly) in the outer compared to the middle regime. Furthermore, the estimated thresholds identified for less frequent trade routes are larger compared to frequently followed trade routes, due to higher market and business risk involved in trading grain to new markets in Russia.

Our results also indicate that the degree of wheat market integration in Russia is a function of distance. The most distant markets report the lowest price transmission elasticities, weakest price adjustment, and highest thresholds. The latter is remarkably high for price pairs including Ural and West Siberia, two peripheral regions located thousands of kilometers away from the major export regions and consumption centers.

Wheat market integration in Russia strengthened significantly during the export ban period. Especially high increases in price transmission elasticities are obtained for price pairs including North Caucasus. We explain this finding with two reasons: First, because of the export ban, the influence of world market conditions on domestic wheat price formations decreased. Thus, the role of common domestic factors increased, strengthening the integration of the domestic wheat market, particularly in regions that are usually involved in grain exports to the world market. Second, due to the severe harvest shortfalls of up to 60% in some regions in 2010/11 and the implemented export ban, interregional trade flows increased considerably from the surplus regions of North Caucasus and West Siberia to the deficit regions, which strengthened domestic wheat market integration in Russia.

Moreover, further analysis of price adjustments for individual price pairs during the export ban period indicates that, even though the general speed of price adjustment increased between wheat prices in Russia, the number of price pairs not adjusting to price equilibrium also increased, possibly because of increased market uncertainties.

Confirmed by increases in thresholds in both trade directions during 2010/11, transaction costs also increased during the export ban period. We trace this back to increased transport costs and increased risk of interregional grain transactions; information provided by the Russian Grain Union confirms these results. First, the government increased railway transport costs by 10% from 2009/10 to 2010/11. Further, grain trade destinations changed and flows of trade reversed within Russia due to the existing ban on grain exports. High trade risk may result from changing trade destinations, which requires involving new trade partners. Thus, transaction costs of trade in Russia increased considerably during the export ban period, owing to increased costs of search and trade risk associated with difficulties in contract enforcement. The transport subsidies provided were too low to prevent increases in the total transaction costs during the export ban period.

Our study offers several important implications in terms of trade policy and food security. First, due to long distances and poor infrastructure, distribution of grains between spatially protracted areas can be challenging. As a result, grain-deficit areas remain increasingly vulnerable in the face of harvest failures. To improve the regional connectivity and cushion potential production shocks, it is important to increase investments in transport infrastructure and storage facilities in the areas where they are underdeveloped.

Second, export restrictions are capable of enhancing regional integration at the expense of activation of domestic trade relations. Based on the study results, we argue that the Russian wheat export ban was indeed effective in terms of insulating the Russian domestic grain markets and achieving a higher degree of wheat market integration within Russia. Although such measures can be relatively effective to cope with grain deficits in the short run, their long-term implications are rather negative for development of grain production. As our results indicate, the Russian wheat market was also characterized by higher transaction costs during the export ban period, resulting from increased uncertainty and market risk. Increased instability of markets due to recurring governmental interventions discourages investments in grain production, negatively affects further development of the grain sector, and has a detrimental effect on the realization of wheat production potential, resulting in implications for future global food security (Fellmann et al., 2014; Lioubimtseva and Henebry, 2012).

Our results are in line with the conclusions of earlier studies (for example, Götz et al., 2013; Götz et al, 2016; Jensen and Anderson, 2017) that find that export restrictions increase grain price levels and introduce instability to the grain markets. The World Trade Organization (WTO) may act as a platform that brings international discipline to trade restrictions. However, this does not eliminate individual countries introducing trade restrictions under the name of economic sanctions (For example, in August 2014, Russia imposed the ban on the import of agricultural and food products from all western countries [Götz and Jaghdani, 2017]), which so far are out of the WTO's control.

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APPENDIX

Table A.3.1.1: Augmented Dickey-Fuller test for prices in levels and first differences

Variable	Determ. component	Lags	Test-stat	Δ Variable	Determ. component	Lags	Test-stat
Central	Constant & trend	2	−2.531	Δ Central	None	1	-7.396^{***}
North Caucasus	Constant & trend	1	−2.287	Δ North Caucasus	None	0	-10.14^{***}
Black Earth	Constant & trend	1	−2.362	Δ Black Earth	None	0	-8.520^{***}
Volga	Constant & trend	2	−2.569	Δ Volga	None	1	-7.252^{***}
Ural	Constant & trend	2	−2.380	Δ Ural	None	1	-7.351^{***}
West Siberia	Constant & trend	2	−2.546	Δ West Siberia	None	1	-7.349^{***}

Note: Lag length selection is based on Schwarz Information Criterion. One-sided p-values are from MacKinnon (1996).
*** $p<0.01$, ** $p<0.05$, * $p<0.10$

Table A.3.1.2: Tests of threshold cointegration

Price pair	Hansen and Seo test [a, †]		Larsen test [b, †]
	Sup-Wald test statistic	5% Critical value	P-value
2009/10			
Central – Black Earth	11.111	18.398	0.060
Central – Volga	17.262	18.596	0.070
Central – Ural	20.363***	18.566	0.210
Central – West Siberia	14.133**	13.109	0.400
North Caucasus – Central	21.037**	19.054	0.020
North Caucasus – Black Earth	13.932*	14.769	0.080
North Caucasus – Volga	21.666***	18.271	0.040
North Caucasus – Ural	24.227***	19.072	0.010
North Caucasus – West Siberia	20.543**	19.377	0.020
Black Earth – Volga	24.383*	05.088	0.040
Black Earth – Ural	25.332***	24.907	0.010
Black Earth – West Siberia	15.223*	16.237	0.080
Volga – Ural	17.746*	18.451	0.460
Volga – West Siberia	12.149*	13.296	0.060
Ural – West Siberia	18.002*	18.528	0.620
2010/11			
Central – Black Earth	18.477**	18.042	0.032
Central – Volga	18.477***	17.512	0.027
Central – Ural	20.360**	19.903	0.080
Central – West Siberia	16.407*	17.643	0.358
North Caucasus – Central	15.189**	14.963	0.081
North Caucasus – Black Earth	15.038*	15.524	0.047
North Caucasus – Volga	23.181**	23.167	0.030
North Caucasus – Ural	23.871***	17.998	0.130
North Caucasus – West Siberia	17.567	23.479	0.080

Black Earth – Volga	23.722**	13.249	0.446
Black Earth – Ural	31.963***	29.530	0.169
Black Earth – West Siberia	25.341***	23.204	0.040
Volga – Ural	24.684**	23.650	0.203
Volga – West Siberia	24.313**	23.285	0.108
Ural – West Siberia	13.070	17.377	0.100

Note:
[a] two-regime TVECM with one threshold.
[b] 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". *** p<0.01, ** p<0.05, * p<0.10

Table A.3.1.3: Wald test for the effects of export ban on price transmission elasticities

	Price transmission elasticity	
Price pairs	Free trade	Effect of export ban
Central – Black Earth	0.940	−0.023
Ural – West Siberia	0.833	0.001
Black Earth – Volga	0.740	0.150
Central – Volga	0.678	0.127
Volga – Ural	0.677	0.167**
Volga – West Siberia	0.571	0.146**
Black Earth – Ural	0.469	0.291***
Central – Ural	0.432	0.267**
Black Earth – West Siberia	0.388	0.247**
Central – West Siberia	0.358	0.231**
North Caucasus – Central	0.346	0.296***
North Caucasus – Black Earth	0.333	0.240**
North Caucasus – Volga	0.267	0.277***
North Caucasus – Ural	0.156	0.287***
North Caucasus – West Siberia	0.132	0.260***

Note: Price pairs are sorted based on the values of price transmission elasticities in 2009/10 in a descending order.
*** p<0.01, ** p<0.05, * p<0.10

Std. Error	t-statistic	P-value
0.025	-0.940	0.349
0.037	0.039	0.977
0.112	1.343	0.183
0.117	1.082	0.282
0.083	2.001	0.048
0.068	2.143	0.035
0.065	4.476	0.000
0.123	2.170	0.034
0.107	2.321	0.022
0.108	2.134	0.035
0.102	2.903	0.005
0.101	2.376	0.019
0.065	4.258	0.000
0.057	5.040	0.000
0.045	5.720	0.000

Table A.3.1.4: Results of TVECM: 2009/10

Price pair (market 1 - market 2)	Lower regime		Middle regime			Upper regime			Total adjustment[a]			
	Sp. Adj. $(\rho_1)^{\dagger}$	P-value	Thresh-old (τ_1)	Sp. Adj. $(\rho_2)^{\dagger}$	P-value	Thresh-old (τ_2)	Sp. Adj. $(\rho_3)^{\dagger}$	P-value	Lower	Middle	Upper	Band of Inaction[c]
Central - Black Earth	−0.212	0.360	*−0.021*	−0.208	0.336	*0.018*	−0.353	0.089	0.340	0.364	0.733	*0.039*
Black Earth - Central	0.340	0.072		0.364	0.035		0.380	0.015				
Central - Volga	−0.077	0.470	*−0.013*	0.088	0.758	*0.003*	−0.183	0.027	0.166	-	0.183	*0.016*
Volga - Central	0.166	0.061		0.044	0.901		0.079	0.370				
Central - Ural	−0.029	0.757	*−0.047*	−0.149	0.259	*0.029*	−0.173	0.030	0.310	-	0.173	*0.076*
Ural - Central	0.310	0.004		0.179	0.214		0.100	0.233				
Central - West Siberia	−0.039	0.646	*−0.062*	−0.102	0.311	*0.021*	−0.166	0.014	0.260	-	0.166	*0.083*
West Siberia - Central	0.260	0.041		0.082	0.574		−0.005	0.955				
North Caucasus - Black Earth	−0.207	0.041	*−0.021*	−0.207	0.041	*0.020*	−0.207	0.041	0.207	0.207	0.207	*0.041*
Black Earth - North Caucasus	−0.018	0.809		−0.018	0.809		−0.018	0.809				
North Caucasus - Central	−0.300	0.025	*−0.030*	−0.316	0.088	*0.020*	−0.168	0.136	0.300	0.316	-	*0.050*
Central - North Caucasus	−0.153	0.187		0.114	0.299		0.031	0.744				
North Caucasus - Volga	−0.169	0.082	*−0.038*	−0.249	0.058	*0.018*	−0.171	0.043	0.169	0.249	0.171	*0.056*
Volga - North Caucasus	−0.055	0.566		−0.108	0.449		−0.064	0.495				

North Caucasus - Ural	−0.153	0.217	*−0.062*	−0.062	0.534	*0.028*	−0.087	0.318	-	0.208	-	*0.090*
Ural - North Caucasus	0.050	0.694		0.208	0.053		0.085	0.361				
North Caucasus - West Siberia	−0.220	0.017	*−0.047*	−0.070	0.516	*0.027*	−0.156	0.051	0.22	0.229	0.156	*0.074*
West Siberia - North Caucasus	0.096	0.402		0.229	0.087		0.069	0.518				
Black Earth - Volga	−0.094	0.086	*−0.046*	−0.146	0.052	*0.011*	−0.094	0.086	0.094	0.146	0.094	*0.057*
Volga - Black Earth	0.022	0.781		−0.003	0.979		0.022	0.781				
Black Earth - Ural	0.043	0.456	*−0.039*	0.001	0.991	*0.050*	−0.072	0.383	0.306	0.134	0.219	*0.089*
Ural - Black Earth	0.306	0.001		0.134	0.088		0.219	0.020				
Black Earth - West Siberia	0.007	0.934	*−0.087*	−0.043	0.474	*0.047*	−0.134	0.179	0.278	-	-	*0.134*
West Siberia - Black Earth	0.278	0.007		0.022	0.749		0.043	0.705				
Volga - Ural	0.052	0.688	*−0.052*	0.038	0.767	*0.026*	0.022	0.855	0.181	-	-	*0.078*
Ural - Volga	0.181	0.104		0.153	0.174		0.099	0.336				
Volga - West Siberia	−0.141	0.274	*−0.056*	−0.201	0.035	*0.035*	−0.288	0.004	-	0.201	0.288	*0.091*
West Siberia - Volga	0.216	0.125		0.098	0.228		−0.026	0.763				
Ural - West Siberia	−0.206	0.072	*−0.027*	−0.186	0.183	*0.012*	−0.206	0.141	0.206	-	-	*0.039*
West Siberia - Ural	0.213	0.157		0.167	0.324		0.011	0.951				

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 of the TVECM significant at least 10% level. [b] The band of inaction is given as the difference between the absolute value of the upper and lower threshold.
The hyphen (-) = not applicable. *** $p<0.01$, ** $p<0.05$, * $p<0.10$

Table A.3.1.5: Results of TVECM: 2010/11

Price pair (market 1 - market 2)	Lower regime			Middle regime			Upper regime		Total adjustment[a]			
	Sp. Adj. $(\rho_1)^\dagger$	P-value	Thresh-old (τ_1)	Sp. Adj. $(\rho_2)^\dagger$	P-value	Thresh-old (τ_2)	Sp. Adj. $(\rho_3)^\dagger$	P-value	Lower	Middle	Upper	Band of Inaction[c]
Central - Black Earth	0.018	0.964	*−0.022*	−0.437	0.096	*0.014*	−0.272	0.369	0.587	0.437	-	*0.036*
Black Earth - Central	0.587	0.098		0.022	0.915		0.301	0.243				
Central - Volga	−0.690	0.005	*−0.018*	−0.290	0.161	*0.008*	−0.168	0.334	0.690	-	-	*0.026*
Volga - Central	−0.142	0.568		0.117	0.566		0.178	0.292				
Central -Ural	−0.416	0.001	*−0.103*	0.035	0.674	*0.031*	−0.191	0.167	0.416	-	0.395	*0.134*
Ural - Central	−0.017	0.889		0.027	0.749		0.395	0.006				
Central -West Siberia	−0.329	0.007	*−0.105*	0.118	0.061	*0.054*	0.158	0.131	0.329	-	0.274	*0.159*
West Siberia - Central	0.040	0.772		0.028	0.764		0.274	0.042				
North Caucasus - Black Earth	−0.244	0.054	*−0.090*	−0.264	0.035	*0.038*	−0.217	0.121	0.244	0.264	-	*0.128*
Black Earth - North Caucasus	−0.014	0.846		−0.075	0.171		0.008	0.921				
North Caucasus - Central	−0.170	0.131	*−0.048*	−0.065	0.765	*0.017*	−0.176	0.156	-	0.306	-	*0.065*
Central - North Caucasus	−0.083	0.287		0.306	0.048		−0.090	0.322				

North Caucasus - Volga	−0.261	0.157	*−0.050*	−0.304	0.082	*0.007*	−0.231	0.210	-	0.304	-	*0.057*
Volga - North Caucasus	−0.145	0.220		−0.012	0.905		−0.155	0.155				
North Caucasus - Ural	−0.323	0.002	*−0.099*	−0.323	0.002	*0.085*	−0.328	0.098	0.323	0.323	0.328	*0.184*
Ural - North Caucasus	−0.036	0.365		−0.036	0.365		−0.149	0.210				
North Caucasus - West Siberia	−0.372	0.003	*−0.053*	−0.305	0.029	*0.075*	−0.407	0.019	0.372	0.305	0.407	*0.128*
West Siberia - North Caucasus	−0.032	0.749		−0.018	0.894		−0.093	0.486				
Black Earth - Volga	0.020	0.903	*−0.039*	0.002	0.991	*0.015*	0.020	0.903	0.352	0.350	0.352	*0.054*
Volga - Black Earth	0.352	0.028		0.350	0.052		0.352	0.028				
Black Earth - Ural	−0.048	0.501	*−0.049*	−0.212	0.084	*0.048*	−0.203	0.330	-	0.212	-	*0.097*
Ural - Black Earth	0.028	0.594		0.002	0.981		0.176	0.337				
Black Earth - West Siberia	−0.246	0.008	*−0.107*	0.041	0.430	*0.071*	−0.063	0.657	0.246	-	-	*0.178*
West Siberia - Black Earth	−0.150	0.186		0.104	0.126		0.003	0.984				
Volga - Ural	−0.179	0.028	*−0.107*	−0.118	0.074	*0.069*	−0.234	0.059	0.179	0.118	0.234	*0.176*
Ural - Volga	−0.006	0.929		0.016	0.773		−0.020	0.856				
Volga - West Siberia	−0.104	0.170	*−0.105*	0.041	0.529	*0.046*	0.105	0.439	-	-	0.418	*0.151*
West Siberia - Volga	0.032	0.679		0.061	0.376		0.418	0.005				
Ural - West Siberia	0.053	0.513	*−0.061*	0.039	0.619	*0.029*	0.039	0.619	0.318	0.300	0.300	*0.090*
West Siberia - Ural	0.318	0.012		0.300	0.020		0.300	0.020				

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 of the TVECM significant at least 10% level. [b] The band of inaction is given as the difference between the absolute value of the upper and lower threshold.
The hyphen (-) = not applicable. *** $p<0.01$, ** $p<0.05$, * $p<0.10$

4 FOOD SECURITY AND THE FUNCTIONING OF WHEAT MARKETS IN CENTRAL ASIA AND THE SOUTH CAUCASUS

4.1 FOOD SECURITY AND THE FUNCTIONING OF WHEAT MARKETS IN CENTRAL ASIA AND THE SOUTH CAUCASUS: A COMPARATIVE PRICE TRANSMISSION ANALYSIS

Earlier versions of this paper were presented as:

- Contributed Paper at the 56th Annual Conference of the German Association of Agricultural Economists (GeWiSoLa) "Agricultural and Food Economy – Regionally Connected and Globally Successful", September 28–30, 2016, Bonn, Germany.
- Contributed Paper at the 155th EAAE Seminar "European Agriculture towards 2030 – Perspectives for further East-West Integration", September 19–21, 2016, Kyiv, Ukraine.
- Contributed Paper at the Armenian Economic Association "2016 annual meetings", June 17–19, 2016, Yerevan, Armenia.
- Invited presentation at the International School of Economics at Tbilisi State University (ISET), June 13, 2016, Tbilisi, Georgia.
- Contributed Paper at the "Caspian and Black Sea Agrarian Congress", April 12–13, 2016, Baku, Azerbaijan.
- Contributed Paper at the IAAE Inter-Conference Symposium "Agricultural Transitions along the Silk Road: Restructuring, Resources and Trade in the Central Asia Region", April 4–6, 2016, Almaty, Kazakhstan.

Study outcomes also constitute a part of the following publications:

- World Bank (2018). Europe and Central Asia – The impacts of the El Niño and La Niña on large grain producing countries in ECA: yield, poverty and policy response. Washington, D.C.: World Bank Group.
- Djuric, I., Götz, L., Svanidze, M., and Glauben, T. (2018). Agricultural market integration in the Commonwealth of Independent States: What are the main driving forces and challenges? In: Egilmez, G. (ed.), Agricultural Value Chain, 139–160: InTechOpen.
- Djuric, I., Götz, L., Svanidze, M., Levkovych, I., Wolz, A. and Glauben, T. (2015). Agricultural market integration of the Commonwealth of Independent States. AGRICISTRADE report deliverable 4.2.

Food security and the functioning of wheat markets in Central Asia and the South Caucasus: A comparative price transmission analysis

Abstract

We investigate wheat price relationships between the import-dependent countries in Central Asia and the South Caucasus and the Black Sea wheat exporters to assess wheat market efficiency which is crucial for ensuring availability and access to wheat and for reducing food insecurity. Results of linear and threshold error correction models suggest strong influence of trade costs on market integration in Central Asia, while those costs are of minor importance in the South Caucasus. In particular, wheat trade in Central Asia is characterized not only by higher transportation costs but also informal payments play a large role. In addition, wheat price volatility is substantially higher in the wheat importing countries of Central Asia compared to the South Caucasus. To foster market functioning, wheat trade should be facilitated by policies reducing trade costs. This includes investments in grain market infrastructure, eliminating informal payments, but also resolving geopolitical conflicts. However, wheat trade in this region is characterized by large distances, low scope for import diversification and repeated export restrictions by Black Sea exporters. Therefore, trade enhancing policies should be complemented with policies increasing wheat self-sufficiency to enhance food security.

Keywords: price transmission, wheat market integration, transportation costs, food security, Central Asia, the South Caucasus

1 Introduction

The efficiency of agricultural and food markets strongly influences food security by determining the availability of food products and the level of end consumer food prices (FAO, 2009). Food prices affect nutritional status, especially of poor households, which spend large shares of their income on food (Matz et al., 2015).

Food insecurity is prevalent in countries of Central Asia and the South Caucasus (Schroeder and Meyers, 2016).[1] Populations in these countries derive on average between 40% and 60% of their total dietary energy supply solely from wheat, which is heavily imported from the wheat exporting countries of the Black Sea region. Specifically, Russia, Kazakhstan, and Ukraine account for over 90% of total wheat imports to Central Asian and South Caucasian countries (UN Comtrade, 2018). The Black Sea region accounts for the largest share of global wheat exports; however, exports from this region are highly unstable due to harvest shortfalls and export restrictions (Fellman et al., 2014). Since wheat is the primary source of calories in Central Asia and the South Caucasus, the efficient functioning of grain markets in those regions is essential for alleviating food insecurity. In the future, harvest shortfalls due to climate-change-related weather extremes are expected to increase in Central Asia (Ubilava, 2017), further increasing the necessity of well-functioning grain markets in this region.

This paper investigates the functioning of domestic wheat markets in wheat import-dependent countries of Central Asia and the South Caucasus by studying the integration of these markets with the wheat export markets in the Black Sea region and global wheat markets.

Well-functioning domestic wheat markets that are strongly integrated in regional or world wheat markets promote the efficient allocation of resources. An integrated market is characterized by comoving prices that are in equilibrium with the prices in spatially separated markets. In a spatially efficient market, the Law of One Price holds, i.e., the price difference

1 Throughout this study, the term "Central Asia" refers to the countries Kyrgyzstan, Tajikistan, and Uzbekistan. The South Caucasus includes Armenia, Azerbaijan, and Georgia.

observed between spatially separated markets equals the respective trade costs at most (Takayama and Judge, 1971).[2] From a dynamic perspective, prices may temporarily deviate from the price equilibrium due to market shocks, but trade arbitrage, with which traders exploit price differences exceeding trade costs, will quickly correct such deviations (Fackler and Goodwin 2001). In that sense, a high level of trade fosters market integration and contributes to the stabilization of prices. Based on the results of a panel analysis of 151 countries, Dithmer and Abdulai (2017) finds that trade openness positively impacts food security. Studies on market integration also provide evidence for market competitiveness. If we find that two markets are strongly integrated, we can also infer that they are competitive, since price differences are quickly arbitraged in strongly integrated markets (Dillon and Dambro, 2017).

As an example, in a strongly integrated market, a regional grain harvest shortfall triggers price increases, which are quickly transmitted to other markets, thereby inducing concomitant trade flows that eventually act to stem rising prices (Goodwin and Piggott, 2001). By contrast, a region that is only weakly integrated in regional and world wheat markets might be restricted from accessing export markets, and then only at high costs (Jamora and von Cramon-Taubadel, 2016). In this case, rising regional prices will induce only limited trade inflows, thereby negatively affecting the availability and access to a sufficient, reasonably priced grain supply.

We analyze how prices observed within the Central Asian wheat markets of Kyrgyzstan, Tajikistan, and Uzbekistan and the South Caucasian wheat markets of Azerbaijan, Armenia, and Georgia relate to prices of the Black Sea wheat export markets (Russia, Ukraine, and Kazakhstan) and the world markets (France and the USA). We complement this price transmission analysis with the analysis of historical wheat price volatility in these markets.

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2 We use the terms "trade costs" and "transaction costs" interchangeably. Transportation costs (sometimes referred to as shipping costs) are only part of trade costs.

Wheat markets in Central Asia and the South Caucasus have only been studied in a rudimentary fashion in the existing literature and their degree of efficiency is clearly an under-researched question. This can, at least in part, be explained by the limited availability of and accessibility to suitable data (Brück et al., 2012). Unlike the case of the Black Sea wheat exporting countries, where strong interest in their respective markets from international agricultural trading companies has spurred private data collection efforts, this kind of data is often not publicly available for the wheat import-dependent countries of Central Asia and the South Caucasus.

Existing studies on wheat markets in the South Caucasus region have found that domestic wheat markets are well integrated into the world market system and are characterized by a symmetrical adjustment of price deviations from the equilibrium (Bluashvili and Safaryan, 2014; Djuric et al., 2017; Katsia and Mamardashvili, 2016). In contrast, grain price relationships across the Central Asian countries indicate more heterogeneous patterns of price transmission, ranging from well-integrated to completely segregated wheat markets (Bobokhonov et al., 2017; Chabot and Dorosh, 2007; Ilyasov, 2016; Ilyasov et al., 2016).

Differing from existing studies, we follow a comparative approach and investigate market integration in the six selected countries of Central Asia and the South Caucasus within a unified price transmission modelling approach. A comparative approach may permit a more comprehensive interpretation of the estimated parameters. In price transmission analysis, the estimated parameters themselves enable judging how well a market is functioning to a limited degree only. We tackle this issue by investigating markets with differing characteristics within a similar modelling approach, allowing the estimated model parameters to be directly compared.

By using the non-linear, threshold-type price transmission model approach (Greb et al., 2013), we explicitly account for trade costs that strongly influences market integration (Fiamohe et al., 2013; Jamora and von Cramon-Taubadel, 2016; Moser et al., 2009; Svanidze and Götz, 2017; van Campenhout, 2007). Poor transportation infrastructure and high shipping costs, as well as excessive bureaucratic requirements, are problematic throughout Central Asia (ADB, 2006; Pomfret, 2016; World Bank, 2011). This is less of a concern for the South Caucasian countries, as the export markets in the Black Sea region can be accessed through Georgia's ports.

The paper is organized as follows: Section 2 provides a general overview of food security and domestic wheat markets in Central Asia and the South Caucasus, while section 3 introduces the model framework and research question. In section 4, we discuss the data and in section 5 we share our empirical results. Policy recommendations and a discussion are provided in section 6, followed by our conclusions in section 7.

2 Food security, the wheat trade, and transportation costs in Central Asia and the South Caucasus

Food insecurity is chronic in most of the Central Asian countries and critical in the South Caucasus region (Akramov, 2012; Bobojonov et al., 2017; Chabot and Tondel, 2011; Swinnen and van Herk, 2011). Stunting in children less than five years of age averages 22% and 17% in Central Asia and the South Caucasus, respectively. In addition, underweighting occurs in 7% of child populations in Central Asia and 4% in South Caucasus children (see Table 4.1.1 for individual shares). The UN's World Food Programme, a humanitarian organization fighting hunger worldwide, also operates in the Central Asian countries of Kyrgyzstan and Tajikistan, as well as in Armenia in the South Caucasus.

In addition, households in these regions spend a large portion of their income on food, as much as 49% on average in Armenia and 63% in Tajikistan, for example (Table 4.1.1). Among all food items, wheat, mainly in the form of bread, accounts for a large share of total daily food calories, ranging from 40% to 60% in both regions. Since household welfare largely depends on the level of food prices, increased food prices often lead to social and political unrest. During recent food price hikes, organized public protests were observed in Uzbekistan in September 2007 (Ortiz et al., 2013); in Tajikistan in February 2008 (RFE/RL, 2008); and in Kyrgyzstan in April 2010 (Swinnen and Van Herck, 2013).

Most governments in Central Asia have emphasized wheat self-sufficiency as an important goal that they aspire to within their national food security policy (FAO, 2015). In Uzbekistan, for example, wheat production is still centrally planned. The government, through its land leasing contracts, sets quotas for the land area under wheat cultivation and defines yield and production targets to be met by farmers. Although input subsidies are provided, the government also obliges farmers to sell 50% of their produce to state enterprises at the predetermined fixed price. State procurement prices are by about three to five times lower than counterfactual market prices (Pugach et al., 2016). For the case of Kyrgyzstan and Tajikistan, even though their National Food Security Programs aim to achieve wheat self-sufficiency, these countries apply more liberal agricultural policy measures and remain heavily depended on wheat imports.

Table 4.1.1: Country-specific indicators in Central Asia and the South Caucasus

	Central Asia			South Caucasus		
Economic indicator / **Country**	**Kyrgyzstan**	**Tajikistan**	**Uzbekistan**	**Armenia**	**Azerbaijan**	**Georgia**
Share of household expenditure on food and non-alcoholic beverages (%), 2012	46	63	31	49	43	35
Share of wheat as % of total food calorie supply (kcal/capita/day), average of 2004–2011	38	52	52	40	56	40
Share of imports in total wheat domestic consumption (%), average of 2006–2014	36	66	22	58	44	93
Prevalence of stunting in children under 5 (%)	18 (2012)	27 (2012)	20 (2006)	21 (2010)	18 (2013)	11 (2009)
Prevalence of underweight in children under 5 (%)	4 (2012)	13 (2012)	4 (2006)	5 (2010)	5 (2013)	1 (2009)

Source: FAOSTAT (2015), USDA-ERS (2016), USDA-FAS (2016), WFP (2016), WHO (2016)

Among the South Caucasian countries, the level of government support is the lowest (practically non-existent) in Georgia and Armenia, and relatively high in Azerbaijan. In particular, farmers in Azerbaijan receive subsidies for fertilizers, fuel, machinery, and seed production, as well as monetary transfers (Robinson, 2008); however, contrary to Uzbekistan, the government of Azerbaijan does not oblige farmers to sell their grain to state procurement agencies. Investments from Kazakhstan also play an important role in the development of the wheat trade and processing sector in Azerbaijan (FAO/EBRD, 2009).

Nonetheless, in the countries of Central Asia and the South Caucasus, domestic wheat production falls very short of meeting local wheat demand. On average, imports account for 41% of wheat consumption in Central Asia and 63% in the South Caucasus (Table 4.1.1). With the increasing impact of climate change and the growing water shortages associated with it, wheat yields are forecasted to decline over time. Also, variability in wheat production, and ultimately wheat imports, are expected to increase in Central Asia (Sutton et al., 2013).

Central Asian countries import their wheat almost exclusively from Kazakhstan, whereas wheat to the South Caucasian countries is mainly imported from Russia, Kazakhstan, and, to a lesser extent, from Ukraine (Fig. 4.1.1).

In the recent past, the Black Sea region's wheat exporting countries experienced severe harvest shortfalls and implemented various export control systems during periods of high and volatile prices (Götz et al., 2016). During wheat export restrictions, wheat imports to countries in Central Asia and the South Caucasus from Russia, Ukraine, and Kazakhstan were substituted by imports from more distant countries, such as Iran and European countries.

Countries of Central Asia and the South Caucasus differ substantially in terms of the structure and size of their transportation costs. The Central Asian countries are landlocked and can access the Black Sea exporting markets only through Kazakhstan (Fig. A.4.1.1, Appendix). In Central Asian countries, wheat is shipped mainly by train and secondarily by truck. Northern Kyrgyzstan and Uzbekistan can import wheat directly from Kazakhstan, whereas most rail shipments to southern Kyrgyzstan and Tajikistan must first pass through Uzbekistan.

In contrast, the South Caucasian country of Georgia utilizes its Black Sea ports, through which wheat can be imported directly from Russia and Ukraine (Fig. A.4.1.1, Appendix). Armenia depends on Georgia's rail network for transporting imported wheat from Georgia's Black Sea ports to its border. Georgia may also import wheat from Kazakhstan by freight train, which passes through Russia and Azerbaijan. Azerbaijan relies on rail shipments of wheat directly from Russia and utilizes the Russian railroads as well to access Ukrainian and Kazakh wheat. Due to the military conflict between Armenia and Azerbaijan, the border between the two countries is closed, forcing Armenia to import Kazakh wheat through Georgia, significantly increasing the price of Kazakh wheat and making it less competitive for Armenia compared to purchasing wheat from other Black Sea export markets.

Countries in the South Caucasus import wheat from Russia and Ukraine nearly twice as cheaply than from Kazakhstan (Table 4.1.2). Higher

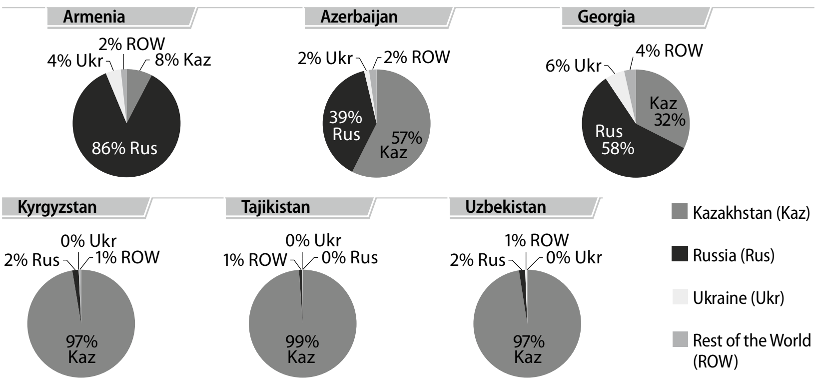

Fig. 4.1.1: Share of the Black Sea region in total wheat imports to Central Asia and the South Caucasus, 2006–2014

Source: UN Comtrade (2018)

Table 4.1.2: Wheat transportation costs

From	Kazakhstan					Russia			Ukraine		
To	Central Asia			South Caucasus		South Caucasus			South Caucasus		
	Kyrgyzstan	Tajikistan	Uzbekistan	Azerbaijan	Georgia	Armenia	Azerbaijan	Georgia	Armenia	Azerbaijan	Georgia
Total transport costs	80–135	120–180	60–110	50–80	70–110	45–60	20–40	15–30	45–60	35–50	15–30
Breakdown of total costs:											
Official rates	30–70	50–100	30–60	50–80	70–110	45–60	20–40	15–30	45–60	35–50	15–30
Informal payments	50–65	70–80	30–50	—	—	—	—	—	—	—	—

Note: — = Not available. Transportation costs (USD/t) are approximate and average estimates.
Source: ADB (2006), Chabot and Tondel (2011), International Seaborne Market (2015), World Bank (2005) and expert interviews

freight rates for wheat imports from Kazakhstan result from large distances and inefficient and outdated logistics systems in Kazakhstan inherited from Soviet Union times.

Shipping costs (official rates) of wheat from Kazakhstan to the Central Asian countries of Kyrgyzstan and Tajikistan are quite comparable to shipping costs to the South Caucasian countries of Azerbaijan and Georgia (Table 4.1.2). However, due to informal payments, the total cost of transportation could be double the official payments in Central Asia (ADB, 2006; Chabot and Tondel, 2011; World Bank, 2005).

Informal payments are paid at custom checkpoints and to the traffic police. For example, a test conducted by the Asian Development Bank (ADB, 2006) shows that informal payments paid by truck drivers on the route between Kyrgyzstan and Kazakhstan are three to four times higher than the official transportation costs. Another experiment by the World Bank (2011) demonstrates that informal payments for in-country transportation of cargos from the northern to the southern part of Kyrgyzstan may account for 9% of total transportation costs. Payments were extracted by transport control authorities and traffic police. Pomfret (2016) points out that trade in Central Asia is not only characterized by high transportation costs, but also by inadequate regional trade infrastructure, resulting in slow movement of cargos and long delays at the border crossing points in this region.

In summary, while the levels of official grain transportation costs in Central Asia and the South Caucasus are rather similar, total transportation costs are substantially higher in Central Asia due to the high informal payments.

3 Methodological framework and model estimation

We investigate the relationships of wheat prices observed in countries in Central Asia and the South Caucasus with Black Sea wheat export markets and world wheat markets in France and the USA within both linear and non-linear price transmission model frameworks.

3.1 Methodological framework

We assume that prices in the spatially separated markets in the wheat import and export markets are linked by spatial price equilibrium, which is represented by

$$P_t^d = \alpha + \beta P_t^e + \varepsilon_t \quad (1)$$

where P_t^d and P_t^e denotes the natural logarithm of domestic and regional/ world export prices and ε_t is a stationary disturbance term. The long-run price equilibrium is characterized by the intercept α and the long-run price transmission elasticity β. If the prices in the domestic and regional or world markets are not in their equilibrium, then traders will make use of this price difference by trade arbitrage and sell wheat on the market with the higher price level. Through price adjustment processes, prices are brought back to their price equilibrium level.

Since Central Asian and the South Caucasian countries are net wheat importers and wheat is traded only in one direction from the Black Sea region to those countries, the wheat price observed in a domestic market (P^d) is considered the dependent variable and regional and world market export prices (P^e) are exogenous variables. Therefore, in this study we use a one-equation error correction model (linear or non-linear) rather than a vector error correction model, which is a system of equations capable of addressing endogeneity.[3]

Unlike the linear error correction model, the threshold error correction model explicitly accounts for the role of transaction costs. According to the spatial trade arbitrage theory (Goodwin and Piggott, 2001), trade arbitrage between two spatially separated markets will take place only if the price difference exceeds transaction costs. Thus, a "regime dependent" price adjustment process may be observed, which can be depicted in a threshold error correction model, where the threshold corresponds to the size of transaction costs.

We use linear (Engle and Granger, 1987) and threshold (Hansen and Seo, 2002) cointegration tests to identify the existence of spatial price equilibrium and to determine whether the price adjustment mechanism is of a linear or non-linear type.

If the price series are linearly cointegrated, then a linear error correction model developed by Engle and Granger (1987) is estimated to quantify the short-run price dynamics in the next step

$$\Delta P_t^d = \gamma \varepsilon_{t-1} + \sum_{i=1}^{k} \delta_i \Delta P_{t-i}^d + \sum_{i=1}^{k} \theta_i \Delta P_{t-i}^e + \omega_t \tag{2}$$

3 In addition to single-equation models, we also use vector error correction model to examine the sensitivity of the estimated model parameters. Confirming our assumption of "small, open economies", the estimation results of the vector error correction model (not reported in this study) indicate that only domestic prices are adjusting to restore price equilibrium between domestic and export markets. We also find the magnitude of the estimated price transmission parameters barely different across the two types of models, further justifying that our chosen model with a single equation does not suffer from endogeneity.

where Δ is the first difference operator and ε_{t-1} represents the error correction term (ECT) variable which is equal to the residuals from equation (1) lagged by one period. γ denotes the speed of adjustment parameter which measures the speed at which deviations from the long-run equilibrium are corrected by trade arbitrage. ΔP^d_{t-i} and ΔP^e_{t-i} represent lagged values of the first difference of the domestic and regional/world price series of lags $i = 1, \dots, k$, ensuring that the model residuals are serially uncorrelated. δ_i and θ_i contain dynamic short-run parameters; ω_t is a conventional residual term with $\omega_t \sim \mathrm{N}(0, \sigma^2)$.

If threshold cointegration is identified between prices, then we estimate the threshold error correction model. Since wheat trade between a wheat importing and a wheat exporting country is uni-directional, we apply a model framework with one threshold and two regimes

$$\Delta P^d_t = \begin{cases} \gamma_1 \varepsilon_{t-1} + \sum_{i=1}^{k} \delta_{1i} \Delta P^d_{t-i} + \sum_{i=1}^{k} \theta_{1i} \Delta P^e_{t-i} + \omega_{1t}, & \varepsilon_{t-1} \le \tau \quad \text{'inner' regime} \\ \gamma_2 \varepsilon_{t-1} + \sum_{i=1}^{k} \delta_{2i} \Delta P^d_{t-i} + \sum_{i=1}^{k} \theta_{2i} \Delta P^e_{t-i} + \omega_{2t}, & \varepsilon_{t-1} > \tau \quad \text{'outer' regime} \end{cases} \qquad (2')$$

where τ denotes the threshold value estimated by the model. The error correction term ε_{t-1} serves as a threshold variable as well. The parameter τ is interpreted as an estimate of transaction costs from the world market to the domestic markets. It includes not only observed transportation costs and customs clearance, but also other unobserved costs, such as physical and institutional infrastructure, ease of accessing market information, and price discounts or premiums paid due to quality differences.

In a threshold error correction model, the threshold variable ε_{t-1} and corresponding threshold parameter τ determine the state of the regime r, $r = 1, 2$. If the magnitude of deviation from the long-run equilibrium is larger than the size of threshold, then the ECT observations are attributed to the "outer" regime ($r = 2$), where strong price adjustment takes place corresponding to the profitable trade arbitrage. However, if the magnitude of disequilibrium, expressed by ε_{t-1} term, does not exceed the size of threshold, then observations are attributed to the "inner" regime ($r = 1$), where the speed of adjustment is much weaker or price adjustment does not occur at all (prices may move independently of each another due to the unprofitability of trade arbitrage).

To obtain threshold parameters, we apply the regularized Bayesian estimator recently developed by Greb et al. (2013) instead of the classic profile likelihood estimator (Hansen and Seo, 2002; Lo and Zivot, 2001).[4] The former is superior due to its better small sample properties and avoidance of arbitrary trimming parameter to generate a threshold estimate. As a result, the Bayesian threshold estimate is well-defined over the entire domain of the threshold parameter. In contrast, a profile likelihood estimator requires a trimming of sample observations to ensure sufficient degrees of freedom for the estimation of model parameters. This procedure might lead to biased model estimation results if the true value of threshold parameters is excluded from the sample. The regularized Bayesian technique, on the other hand, succeeds in retaining all sample observations in the estimation process by penalizing differences between regimes and keeping them small when data contains little information.

Though an error correction model became the benchmark in examining spatial price linkages and market integration in empirical studies, this model approach yet faces several limitations. First, it is based on the assumption that transaction costs are stationary over time and are equal to a constant proportion of commodity prices. On the other hand, if this assumption fails, implying that actual transaction costs are indeed nonstationary, then the lack of linear or threshold cointegration can be wrongly interpreted as evidence of market inefficiencies (Fackler and Goodwin, 2001). Second, the spatial price transmission analysis does not account for the actual trade flows and transaction costs data (Barrett, 1996). The parity bounds model is an alternative approach to studying market integration with actual transportation costs being accounted for; however, as continuous times series data on transportation costs are not available

4 We are grateful to Friederike Greb for supplying her R script on the estimation of the threshold vector error correction model (with two thresholds) through an improved regularized Bayesian estimator. We modified the original code to adjust it to the threshold error correction model representation with one threshold and no constant, as given in equation (2').

for Central Asia and the South Caucasus, we use more parsimonious price transmission models, allowing us to analyze market integration based on the price series data only. Third, we conduct a price transmission analysis in a bivariate setup, allowing for a pairwise price analysis only, whereas several prices at different locations across space may also be simultaneously determined, which can be analyzed within a multivariate price transmission model. Nonetheless, the multivariate analysis of spatial price linkages so far has only been possible for the linear modelling of price linkages. In contrast, the analysis of the spatial integration of grain markets, particularly in Central Asia, explicitly requires accounting for the influence of trade costs, which is achieved by using the threshold error correction model, which can only be implemented in a bivariate setup.

3.2 Model estimation

Initially, we estimate the parameters of the long-run price equilibrium (1) by the ordinary least squares (OLS) method.

If the price series are found to be linearly cointegrated, we apply the linear error correction model framework following Engle and Granger's (1987) approach. If the price series are found to be cointegrated in a non-linear fashion, we then estimate the threshold error correction model (Greb et al., 2013).

Next, the threshold parameters in equation (2') are identified using the regularized Bayesian technique. A function to choose the optimal threshold value of ECTs is called the posterior median and is constructed as follows:

$$\int_{\min(\varepsilon_{t-1})}^{\hat{\tau}_{rB}} P_{rB}(\tau|\Delta P, X)d\tau = 0.5 \quad (3)$$

where X is a $n \times d$ matrix that compactly stacks together columns of ECTs and values of lagged terms. $P_{rB}(\tau|\Delta P, X)$ denotes marginal posterior density, which is well defined across the space of all possible threshold parameter $T = \{\tau| \min(\varepsilon_{t-1}) < \tau < \max(\varepsilon_{t-1})\}$. In the previous expression, τ is the optimal threshold that separates the space into two regimes and satisfies the requirement that $\tau > 0$. Computation is based on a prior $P_{rB}(\tau|X) \propto I(\tau \in T)$ for τ, where $I(\cdot)$ is an indicator function providing for switching between regimes.

Lastly, in choosing a threshold estimate, we estimate the additional short-run price transmission parameters of the threshold error correction model in equation (2′) separately in "outer" and "inner" regimes with the restricted maximum likelihood method that is implemented through mixed-effects modelling using an "nlme" package in R (Pinheiro et al., 2017).

4 Data and data properties

This section provides an overview of the sources and characteristics of the wheat prices, which serve as the basis for this price transmission and volatility analysis.

4.1 Data

We use a unique database covering wheat prices for 11 countries (Table 4.1.3). As pointed out above, suitable wheat price data for the import-dependent countries is scarce. Price data is often simply not available publicly, as for Uzbekistan, for example, or it can be accessed only through personal contacts, as in the case of Azerbaijan. The national statistics agency of Uzbekistan does not monitor the wheat price data. The data that we use in our analysis is directly gathered during 2001 and 2009 at the central retail market in Urgench (Khorezm region) within the KHOREZM project. This data is collected in a consistent and systematic way and is a part of more comprehensive database of the project.[5]

5 Mori Clement et al. (2014) discusses the project data in detail; the project website www.zef.de/khorezm provides more information on the project itself.

Our data set comprises 95 observations for each price series covering the period from October 2006 to August 2014 (Table 4.1.3). One exception is the data for Uzbekistan, which comprises 39 observations of wheat price series and covers the period from October 2006 to December 2009.

Table 4.1.3: Data description

<table>
<tr><th></th><th></th><th>Country</th><th>Price</th><th>Data source</th></tr>
<tr><td rowspan="6">Domestic wheat price</td><td rowspan="3">South Caucasus</td><td>Armenia</td><td>Producer price, AMD/t</td><td>Statistics office</td></tr>
<tr><td>Azerbaijan</td><td>Producer price, AZN/t</td><td>Statistics office</td></tr>
<tr><td>Georgia</td><td>Import price (CIF), GEL/t</td><td>Statistics office</td></tr>
<tr><td rowspan="3">Central Asia</td><td>Kyrgyzstan</td><td>Retail price, KGS/t</td><td>WFP</td></tr>
<tr><td>Tajikistan</td><td>Retail price, TJS/t</td><td>WFP</td></tr>
<tr><td>Uzbekistan</td><td>Retail price, UZS/t</td><td>ZEF/UNESCO</td></tr>
<tr><td rowspan="6">Export wheat price</td><td rowspan="4">Black Sea</td><td>Kazakhstan_s</td><td>Export price (FOB), USD/t</td><td>Kazakh-Zerno</td></tr>
<tr><td>Kazakhstan_n</td><td>Export price (FOB), USD/t</td><td>APK-Inform</td></tr>
<tr><td>Russia</td><td>Export price (FOB), USD/t</td><td>APK-Inform</td></tr>
<tr><td>Ukraine</td><td>Export price (FOB), USD/t</td><td>APK-Inform</td></tr>
<tr><td rowspan="2">Reference markets</td><td>France</td><td>Export price (FOB), USD/t</td><td>HGCA</td></tr>
<tr><td>USA</td><td>Export price (FOB), USD/t</td><td>USDA</td></tr>
</table>

We use retail prices for the analysis of the grain markets' integration in Central Asia and producer and import prices for the grain markets in the South Caucasus. Using the various types of wheat prices may influence the size of parameter estimates to some degree. In particular, attributable to the differences in price levels at the various stages of the supply chain, an analysis with retail prices may result in the underestimation of the long-run price transmission parameter and the speed of adjustment parameter compared to the parameter estimated with producer or import prices. Contrasting, thresholds for prices pairs including retail prices are rather overestimated compared to price pairs with producer and import prices. The domestic prices in the Georgian grain market are well represented by the wheat import (CIF) prices since more than 90% of total wheat supplied on the domestic market is imported.

We use wheat export prices observed in northern Kazakhstan to serve as the reference price for the South Caucasian importing countries.

In addition, a wheat export price observed in southern Kazakhstan is used as the reference price for exports to the neighboring Central Asian countries.

Wheat export prices for Russia and Ukraine have 15 and 16 missing observations, accounting for 16% and 17% of the sample, respectively. Export prices are not observed when the wheat trade was limited by wheat export restrictions in both countries. The effect of export restrictions on wheat prices in Russia and Ukraine is addressed by Götz et al. (2013, 2016). In order to create a continuous time series, the missing observations are filled using a linear imputation technique, making use of the Kazakh wheat export price, which is highly correlated with the Russian and Ukrainian prices. Since wheat trade is usually priced in US dollars, all local wheat price series are transformed to US dollars.

From this database, we built 30 bivariate price pairs, each consisting of a domestic price of six importing countries and an exporting price of five exporting countries (Fig. 4.1.2). We use the Kazakh wheat export price of the northern region with price pairs including the domestic price in a South Caucasian country. Additionally, we built three price pairs by combining the domestic price of a Central Asian country with a southern Kazakhstan wheat export price.

4.2 Data properties

Fig. 4.1.3 makes evident that, on average, the median and variation of the domestic wheat prices in Central Asian countries are higher than in the South Caucasian countries. Relatively high price levels are typical for domestic markets in landlocked countries. However, high price levels observed in Central Asia might be explained in part by the type of wheat prices in the three Central Asian countries: They are retail prices for domestically grown wheat. They contrast with the wheat prices in Armenia and Azerbaijan, which are producer prices; in Georgia, the reported domestic wheat price level is the CIF import price.

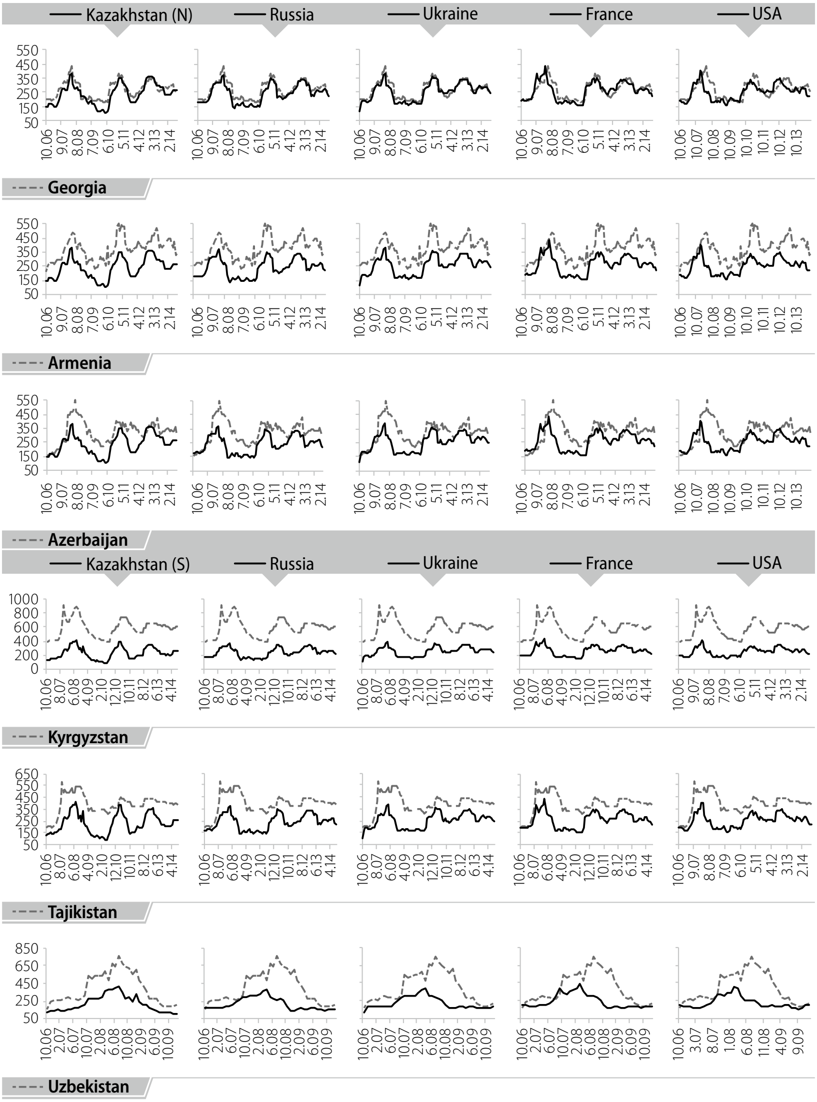

Fig. 4.1.2: Analyzed price pairs

Source: See Table 4.1.3

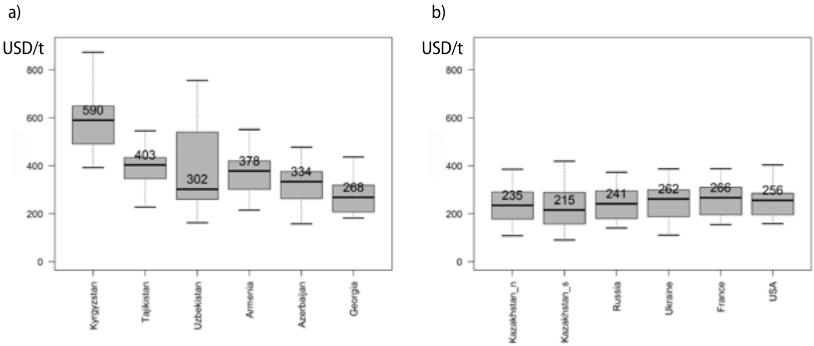

Fig. 4.1.3: Boxplot of wheat price series for (a) domestic prices in wheat importing countries and (b) export prices in wheat exporting countries

Source: See Table 4.1.3

In addition, the wheat quality and variability of yields from year to year might influence the distributional characteristics of the wheat prices. For instance, the relatively low median domestic wheat price in Tajikistan may correlate with the generally low quality of domestically grown wheat due to unfavorable climatic conditions and lack of irrigation systems, whereas wheat produced in Kyrgyzstan is of relatively higher quality.

The lowest median wheat price is also observed in Uzbekistan, where domestic wheat production is highly supported by the government, but, as noted previously, farmers must also sell a portion of their wheat to state-owned enterprises at relatively low prices fixed by the government.

The domestic wheat price in Armenia, the landlocked country in the South Caucasus that cannot trade directly with Azerbaijan due to an active military conflict, represents the highest median price. This contrasts with Georgia, whose Black Sea ports provide direct access to the world market, where the wheat price is characterized by the lowest median value and least price variation.

The distribution of wheat prices in the wheat exporting countries is much more homogeneous. Minor differences in median values across countries might be explained by varying wheat quality grades. For example, the median export price is the highest for wheat of grade one from France, followed by wheat of grade two exported from the USA, and then exports of mostly wheat of grade three from Russia.

The interquartile range and amplitude of wheat price variation is the widest and the median is the lowest for wheat export prices in southern Kazakhstan when compared with the northern region or even other wheat exporting countries. We suspect that the volatile market situation in Central Asian importing countries is influencing export price formation in southern Kazakhstan, as reflected in a relatively large interquartile range. Also, due to the low consumer income levels in the Central Asian countries, the quality of the wheat exported to the Central Asian countries may be lower, as reflected by the lower median wheat price in southern Kazakhstan compared to that in northern Kazakhstan.

A further basic characteristic of the wheat price series is their volatility, indicating the degree of risk that prevails in the wheat markets. High price volatility results in suboptimal level of production, increasing production costs, and reducing incentives for investments. Historical price volatility of each individual price series is measured non-parametrically as the standard deviation (σ_i) of the returns of a price series given as:

$$\sigma_i = 100\sqrt{1/T\sum_{t=1}^{T}(p_{it} - \overline{p}_i)} \qquad (4)$$

where p_{it} denotes price return in time t for country i calculated as $p_{it} = ln(P_{it}/P_{it-1})$ with p_{it} being the price of wheat expressed in USD/t and $\overline{p}_i$ denoting the mean of price returns for country i : $\overline{p}_i = \frac{1}{T}\sum_{t=1}^{T} p_{it}$.

We found price volatility in domestic markets during the period 2006–2014 to be the highest in Central Asian countries, whereas it is significantly lower in South Caucasian countries (Fig. 4.1.4). This might be explained by the relatively inelastic wheat supply, which is characteristic for the markets in the landlocked Central Asian import-dependent countries. In those countries, grain storage facilities are extremely limited (World Bank 2011) and access to international grain markets incurs high transportation costs.

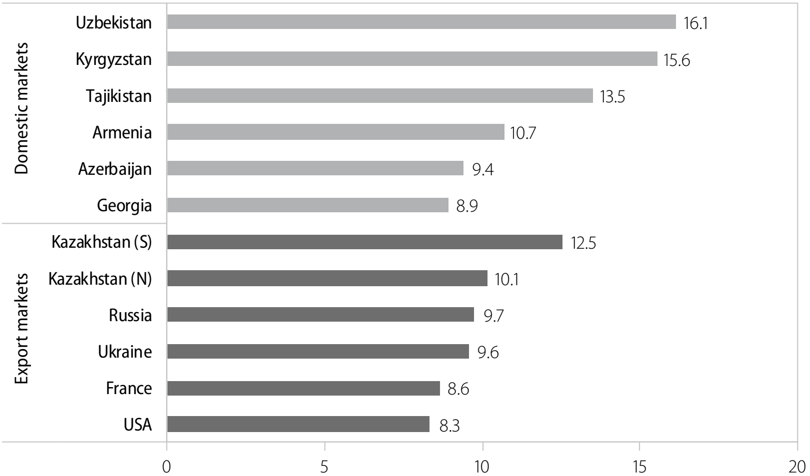

Fig. 4.1.4: Wheat price volatility in wheat importing and exporting countries

Source: See Table 4.1.3

5 Empirical results

To specify a suitable price transmission model framework for each selected price pair, the existence of a meaningful spatial price equilibrium needs to be confirmed. Therefore, we tested all price series for the existence of a unit root and the price pairs for the presence of linear and threshold cointegration. In section 5.1 we present and interpret the results of the unit root and cointegration tests. This will be followed by section 5.2 with the estimated parameters of the price transmission models for 24 out of 30 analyzed price pairs evaluated against a background of comprehensive qualitative knowledge of the wheat markets in those countries.

5.1 Test on the existence of a unit root and cointegration

Results of the ADF test (Dickey and Fuller, 1981) suggest that all wheat prices contain a unit root in level and are stationary in first differences at the 5% level of significance.[6] Results of a traditional unit root test will be biased towards nonstationarity if structural breaks resulting from, for example, policy changes or macroeconomic shocks are ignored in the time series. Therefore, we conducted the breakpoint ADF test (Perron and Vogelsang, 1992) to account for the possible influence of export restrictions implemented in the grain export markets of the Black Sea region in 2007–08 and 2010–11. Results indicate that all price series again contain a unit root at the 10% level of significance, confirming that all price series are integrated of order one.

Since the price series are identified as nonstationary, cointegration of the price pairs is required to keep the estimated spatial price equilibrium regression from being spurious but rather meaningful (Granger and Newbold, 1974).

We applied the linear cointegration test by Engle and Granger (1987) with the null hypothesis of no cointegration against an alternative of linear cointegration.[7] We also applied the threshold cointegration test by Hansen and Seo (2002), which examines threshold cointegration within a one-threshold model corresponding to the market setup in Central Asia and the South Caucasus (compare section 3.1).

The Engle and Granger's test confirms linear cointegration for all price pairs containing a domestic wheat price of a South Caucasian country at the 5% level of significance (Table A.4.1.1, Appendix). However, Engle and Granger's test suggests linear cointegration in just seven out of 15 cases for all price pairs that contain a domestic price of a Central Asian country. Especially, the domestic price series in Kyrgyzstan and Tajikistan are linearly cointegrated with the regional wheat export prices in

6 Results are available from the authors upon request.

7 We assess Engle and Granger test as more suitable for evaluating linear cointegration compared to Johansen's (1988) test of linear cointegration. We explain this by studying wheat market pairs with one-directional trade flows (compare Section 4.1.).

southern Kazakhstan and the world wheat prices in France and the USA. Furthermore, linear cointegration is not verified for any of the price pairs that include Uzbekistan's domestic wheat price. One exception is the price pair Uzbekistan-southern Kazakhstan, which we find to be linearly cointegrated.

Like the results of the linear cointegration test, the Hansen and Seo test on threshold cointegration indicates linear cointegration at the 5% level of significance for all price pairs containing a domestic wheat price of a South Caucasian country (Table A.4.1.1, Appendix). In contrast, for the price pairs containing prices from Kyrgyzstan and Kazakhstan, Kyrgyzstan and Russia, Tajikistan and Kazakhstan, and Tajikistan and Russia, this test suggests threshold cointegration at the 5% level of significance. Threshold cointegration could not be confirmed for the 11 other price pairs constructed by combining a Central Asian domestic wheat price with an export market's wheat price.

With the results of the linear and threshold cointegration tests, we form the cointegration patterns for the 30 price pairs presented in Table 4.1.4. All price pairs involving a wheat price of a South Caucasian country are cointegrated linearly, suggesting that domestic prices adjust uniformly to changes in an export price regardless of the level of trade costs.

By contrast, threshold cointegration is identified between wheat prices of Kyrgyzstan and Kazakhstan, Kyrgyzstan and Russia, Tajikistan and Kazakhstan, and Tajikistan and Russia. This suggests that, in contrast to the South Caucasus, transaction costs play a much larger role in the co-movement of Central Asian domestic wheat prices with export prices in regional markets.

Furthermore, the threshold cointegration test does not indicate the presence of threshold effects in price relationships between domestic wheat prices in Central Asia and the South Caucasus and world export prices in France and the USA. Due to the vast distances involved and lack of well-established transportation infrastructure, transportation costs are prohibitive, thus discouraging wheat imports to Central Asia and the

Table 4.1.4: Pattern of cointegration and selection of error correction models

Price series	Cointegration pattern: Linear	Cointegration pattern: Threshold	Estimated error correction model (ECM)
$P_t^{arm} - P_t^{kaz\_n}$	✓	x	Linear ECM
$P_t^{arm} - P_t^{rus}$	✓	x	Linear ECM
$P_t^{arm} - P_t^{ukr}$	✓	x	Linear ECM
$P_t^{arm} - P_t^{frn}$	✓	x	Linear ECM
$P_t^{arm} - P_t^{usa}$	✓	x	Linear ECM
$P_t^{azn} - P_t^{kaz\_n}$	✓	x	Linear ECM
$P_t^{azn} - P_t^{rus}$	✓	x	Linear ECM
$P_t^{azn} - P_t^{ukr}$	✓	x	Linear ECM
$P_t^{azn} - P_t^{frn}$	✓	x	Linear ECM
$P_t^{azn} - P_t^{usa}$	✓	x	Linear ECM
$P_t^{geo} - P_t^{kaz\_n}$	✓	x	Linear ECM
$P_t^{geo} - P_t^{rus}$	✓	x	Linear ECM
$P_t^{geo} - P_t^{ukr}$	✓	x	Linear ECM
$P_t^{geo} - P_t^{frn}$	✓	x	Linear ECM
$P_t^{geo} - P_t^{usa}$	✓	x	Linear ECM
$P_t^{kyr} - P_t^{kaz\_s}$	✓	✓	Threshold ECM
$P_t^{kyr} - P_t^{rus}$	x	✓	Threshold ECM
$P_t^{kyr} - P_t^{ukr}$	x	x	None
$P_t^{kyr} - P_t^{frn}$	✓	x	Linear ECM
$P_t^{kyr} - P_t^{usa}$	✓	x	Linear ECM
$P_t^{taj} - P_t^{kaz\_s}$	✓	✓	Threshold ECM
$P_t^{taj} - P_t^{rus}$	x	✓	Threshold ECM
$P_t^{taj} - P_t^{ukr}$	x	x	None
$P_t^{taj} - P_t^{frn}$	✓	x	Linear ECM
$P_t^{taj} - P_t^{usa}$	✓	x	Linear ECM
$P_t^{uzb} - P_t^{kaz\_s}$	✓	x	Linear ECM
$P_t^{uzb} - P_t^{rus}$	x	x	None
$P_t^{uzb} - P_t^{ukr}$	x	x	None
$P_t^{uzb} - P_t^{frn}$	x	x	None
$P_t^{uzb} - P_t^{usa}$	x	x	None

Note: "None" indicates that cointegration tests do not suggest linear or threshold cointegration; hence, estimations are not conducted for the respective price pairs.

South Caucasus from those internationally important wheat exporting countries.[8]

On the other hand, just as in the countries of the South Caucasus, in Central Asian Kyrgyzstan and Tajikistan, domestic wheat prices are linearly cointegrated with the world wheat prices in France and the USA, highlighting the importance of information flows from the international to domestic wheat markets.

Neither linear nor threshold cointegration is established between domestic wheat prices in Central Asia and the wheat export prices in Ukraine. In contrast to prices in the South Caucasus, which we find to be linearly cointegrated with the Ukrainian wheat export prices, Central Asian countries do not import wheat from Ukraine because of the relatively long distance between the countries (compare Fig. 4.1.1).

Compared with the other Central Asian countries, empirical evidence on wheat market integration is the weakest for Uzbekistan. We find the Uzbek wheat price to be linearly cointegrated solely with the wheat export price in southern Kazakhstan. Long-run price equilibrium is not established between Uzbekistan and any other export market in the Black Sea region or international markets. This may be explained by the fact that the Uzbek wheat market is one of the most comprehensively regulated markets in Central Asia, with governmental input cost subsidies, wheat price controls, and state grain buying programs, among others.

5.2 Price transmission model estimation results

We analyze the price relationships between selected domestic wheat prices in Central Asia and the South Caucasus and export prices in the Black Sea and international markets within linear and threshold error correction model frameworks. The price transmission model estimates are

8 As an exception, some grain imports from European countries are observed by the countries of the South Caucasus during wheat export restrictions of Kazakhstan, Russia and Ukraine (compare section 2).

evaluated for characteristics of spatial price equilibrium and error correction behavior, with the role of trade costs explicitly accounted for.

Spatial price equilibrium

In general, our results suggest that the comovement of domestic prices with export prices in the Black Sea region and world markets is stronger in the South Caucasus than in Central Asia (Table 4.1.5).

Table 4.1.5: Estimated parameters of the long-run price equilibrium

a. Price transmission elasticity

Export markets	Kyrgyzstan	Tajikistan	Uzbekistan	Central Asia (avg.)	Armenia	Azerbaijan	Georgia	South Caucasus (avg.)
Kazakhstan	0.48	0.40	1.06		0.55	0.55	0.62	
Russia	0.54	0.45	–		0.63	0.49	0.74	
Ukraine	–	–	–		0.71	0.62	0.77	
Black Sea (avg.)	0.51	0.43	–	0.47	0.63	0.55	0.71	0.63
France	0.57	0.49	–		0.62	0.51	0.75	
USA	0.61	0.59	–		0.71	0.60	0.79	
World (avg.)	0.59	0.54	–	0.57	0.67	0.56	0.77	0.67

b. Intercept

Export markets	Kyrgyzstan	Tajikistan	Uzbekistan	Central Asia (avg.)	Armenia	Azerbaijan	Georgia	South Caucasus (avg.)
Kazakhstan	3.78	3.80	0.25		2.91	2.78	2.20	
Russia	3.41	3.52	–		2.48	3.08	1.53	
Ukraine	–	–	–		1.97	2.35	1.31	
Black Sea (avg.)	3.60	3.66	–	3.63	2.45	2.74	1.68	2.29
France	3.20	3.25	–		2.45	2.92	1.42	
USA	2.97	2.68	–		2.01	2.43	1.22	
World (avg.)	3.09	2.97	–	3.03	2.23	2.68	1.32	2.08

Note: – = no cointegration relationship exists between the prices.

Price changes in the regional Black Sea wheat export markets are on average by 16% more completely transmitted to domestic wheat prices in the South Caucasus (0.63 on average) as compared to Central Asia (0.47 on average). By way of example, if the wheat export price in southern Kazakhstan increases by 10%, then the wheat price in Kyrgyzstan increases by 4.8%. Comparing domestic markets across regions, price changes are again less strongly transmitted from the world to domestic markets in Central Asia, with the long-run price transmission elasticity ranging between 0.40 and 0.61, compared to the South Caucasus, for which price transmission elasticity varies between 0.49 and 0.79.

With respect to Central Asian countries, our results suggest that the wheat market in Uzbekistan is solely integrated with the wheat market in Kazakhstan, but, on the other hand, segregated from the wheat export markets in Russia, Ukraine, France, and the USA. Specifically, wheat prices in Uzbekistan almost perfectly comove with wheat prices in southern Kazakhstan. This might be explained by the dominance of the Uzbek state-run enterprise that centralizes the trade of wheat (Bobojonov et al., 2017).

Among other Central Asian countries, the Kyrgyz wheat market (0.48) is the most strongly integrated with the wheat market in Kazakhstan, followed by Tajikistan (0.40). Kazakh wheat is exported to Kyrgyzstan by a direct railway line through a common border, whereas Kazakh wheat is mainly exported to Tajikistan through Uzbekistan.

The Kyrgyz and Tajik markets are more strongly integrated with export markets in Russia than in Kazakhstan, although the amount of wheat imported by Kyrgyzstan and Tajikistan originating in Russia is negligibly small. Moreover, if Kyrgyzstan and Tajikistan import Russian wheat, then the railway passes through Kazakhstan, suggesting that the transportation costs of wheat from Russia are higher. Obviously, the domestic wheat price observed in Kyrgyzstan and Tajikistan is more strongly influenced by the Russian wheat export price than by the wheat export price observed at the southern border of Kazakhstan.

Within the South Caucasus region, prices in Georgia's wheat market exhibit the strongest comovement with the export prices in the Black Sea grain exporting countries (0.71 on average), followed by prices in

Armenia (0.63 on average). On the other end of the spectrum is Azerbaijan, with the weakest price comovement on average at 0.55.

Specifically, price changes in the Russian export market are transmitted to the domestic wheat market in Georgia by 74%, Armenia by 63%, and Azerbaijan by 49%.

Wheat price changes in Kazakhstan, compared with Russia's, are transmitted to a lesser degree to the wheat prices in Armenia and Georgia, which is in line with the observed wheat transportation costs (compare Table 4.1.2).

Although transportation costs of wheat imports to Azerbaijan are higher from Kazakhstan compared to Russia, wheat prices in Azerbaijan comove more strongly with prices in Kazakhstan. This could be explained by the strong business ties between Kazakhstan and Azerbaijan, which indicates that bargaining, search and information costs, as well as other parts of transaction costs usually not subject to empirical investigation, are lower from Kazakhstan to Azerbaijan than from the other Black Sea export markets. Moreover, Azerbaijani importers prefer Kazakh wheat with its high protein content over Russian wheat, resulting in a higher share of wheat imports from Kazakhstan compared to Russia among total Azerbaijani wheat imports.

Estimation results also indicate that long-run price transmission from wheat markets in France and the USA to the South Caucasian and Central Asian wheat markets is as high from markets in the Black Sea region, or in some cases even higher. This result is striking since neither the South Caucasian nor Central Asian countries import wheat from France or the USA. The strong comovement with wheat prices in the USA can be explained by the dominating role of the CBOT wheat price for price formation in those markets. According to information provided by traders, the USA CBOT price data can usually be monitored by all market participants, and it serves as a benchmark against which prices generally are negotiated in the wheat trade.

Finally, the long-run price equilibrium is further characterized by the intercept parameter, which corresponds to the transaction costs of the wheat trade. Our results suggest larger intercept values for the price relationships involving Central Asian countries and the Black Sea regional exporters (3.63 on average) compared to those involving the South Caucasian countries (2.29 on average). This supports our previous findings (see section 2), indicating that total transportation costs are significantly higher in the landlocked countries of Central Asia than in the South Caucasus. Similarly, results of the threshold and linear cointegration tests suggest that trade costs play a large role in the wheat trade of the Central Asian countries.

The particularly low value of the intercept (1.68 on average) for the price pairs involving the wheat price in Georgia can be explained by Georgia's direct access to the Black Sea market via its own ports, and thus its generally lower transportation costs.

Correction of the temporary disequilibrium

Well-functioning markets are characterized by rapid correction of short-run deviations from the long-run spatial price equilibrium, which is reflected by the large value of the speed of adjustment parameter. Our results suggest that the speed of adjustment of prices in the South Caucasian countries is generally higher than in the Central Asian countries (Table 4.1.6).

Concerning Central Asian markets, the highest speed of price adjustment is identified for the wheat price in Uzbekistan, which corrects deviations from the long-run equilibrium with the export price in southern Kazakhstan at a speed of adjustment equal to 0.65. We explain the very quick elimination of price disequilibrium in Uzbekistan by the country's centralized state trading system. Wheat prices in Kyrgyzstan and Tajikistan both adjust price deviations from the price equilibrium with the Kazakh export prices more quickly (0.35 and 0.32 in the "outer" regime) than with the Russian export prices (0.18 and 0.13 in the "outer" regime). We trace this pattern of short-run price dynamics back to the wheat transportation costs.

In the South Caucasian countries, we find that the speed of adjustment of wheat prices with the export prices of the Black Sea wheat

Table 4.1.6: Estimated parameters of the short-run price transmission process

a. Speed of adjustment

Export markets	Kyrgyzstan	Tajikistan	Uzbekistan	Armenia	Azerbaijan	Georgia
Kazakhstan	−0.10, −0.35*** [0.07, 0.08]	−0.08**, −0.32** [0.04, 0.07]	−0.65***	−0.26*** [0.07]	−0.20*** [0.05]	−0.28*** [0.07]
Russia	−0.15**, −0.18*** [0.06, 0.06]	−0.11*, −0.13*** [0.04, 0.06]	–	−0.31*** [0.06]	−0.16*** [0.04]	−0.36*** [0.10]
Ukraine	–	–	–	−0.39*** [0.07]	−0.19*** [0.04]	−0.38*** [0.13]
Black Sea (avg.)	−0.15, −0.27	−0.10, −0.23	–	−0.32	−0.18	−0.34
France	−0.15*** [0.05]	−0.12*** [0.04]	–	−0.28*** [0.06]	−0.15*** [0.04]	−0.29*** [0.10]
USA	−0.13*** [0.04]	−0.12*** [0.04]	–	−0.28*** [0.06]	−0.17*** [0.05]	−0.29*** [0.05]
World (avg.)	−0.14	−0.12	–	−0.28	−0.16	−0.29

b. Thresholds

Export markets	Kyrgyzstan	Tajikistan	Uzbekistan	Central Asia (avg.)
Kazakhstan	0.17	0.21	–	0.19
Russia	0.18	0.24	–	0.21
Ukraine	–	–	–	–
Black Sea (avg.)	0.175	0.225	–	0.20

c. Percentage distribution of observations between regimes (“inner”; “outer”)

Export markets	Kyrgyzstan	Tajikistan	Uzbekistan	Central Asia (avg.)
Kazakhstan	90%, 10%	95%, 5%	–	92%, 8%
Russia	88%, 12%	90%, 10%	–	89%, 11%
Ukraine	–	–	–	–
Black Sea (avg.)	89%, 11%	92%, 8%	–	91%, 9%

Note: – = No cointegration relationship exists between the prices. Standard errors are shown in square brackets.
* $p<0.10$, ** $p<0.05$, *** $p<0.01$

exporting countries is the highest in Georgia (0.34), followed by Armenia (0.32), and Azerbaijan (0.18), reflecting respective transportation cost levels.

The size of the thresholds identified in the threshold error correction model for price pairs containing Tajik wheat prices (0.225, on average) are 0.05 higher than the thresholds estimated for the price pairs containing domestic wheat prices in Kyrgyzstan (0.175, on average). These estimates of transaction costs for Tajikistan and Kyrgyzstan clearly correspond with the respective distance to the export markets in Kazakhstan and Russia.

The degree of market integration may also be characterized by the percentage distribution of observations in the "inner" and "outer" regimes. A higher share of observations in the "inner" regime indicates that fewer instances of market disequilibrium are observed and thus evidences stronger market integration.

The distribution of the price disequilibrium term in different regimes indicates that domestic wheat prices in Central Asia are more often in an equilibrium relationship with the export price in Kazakhstan (92%) than in Russia (89%). This proves that domestic wheat markets in Central Asia are more strongly integrated with the export market in Kazakhstan than in Russia.

6 Policy recommendations and discussion

Based on the results of our analysis, we identify five points of departure for policies to improve the functioning of wheat markets and to raise food security in Central Asia and the South Caucasus (Table 4.1.7).

As our results indicate, trade costs are high in Central Asia, hindering the efficient functioning of grain markets within the region. By reducing trade costs, the wheat trade between the wheat exporting and wheat importing countries is spurred, which contributes to stabilizing prices and strengthening market integration. Investments in transport infrastructure, public or private, are fundamental for reducing transportation costs in Central Asia. In this context, the Belt and Road Initiative project

(HKTDC, 2017), which aims to facilitate intra-regional trade in Central Asia, may provide a suitable platform for improving the region's transportation system.

In addition, the governments of the Central Asian countries should give priority to designing and implementing effective policies for eliminating informal payments, which are another significant factor impacting high transportation costs in the region.

We also find that wheat price volatility is significantly higher in Central Asia than in the South Caucasus or the Black Sea region. An increase in domestic wheat storage facilities in the Central Asian countries, where the wheat storage capacity is less than a week (FEWS NET, 2016), would facilitate managing the wheat price risk and contribute to stabilizing wheat prices and reducing price volatility. Grain stocks could also serve as a crisis measure. For example, strongly increasing wheat prices could be counteracted by releasing grain stocks (Schmitz and Kennedy, 2016).

Our analysis has identified that in the South Caucasus, Armenia has the least diversified grain imports and the highest trade costs compared to other neighboring countries in the region. In Armenia wheat trade costs could moreover be reduced by resolving geopolitical conflict with Azerbaijan. If Armenia and Azerbaijan would open their closed border for cargo transiting at least, then Armenia could directly import wheat from

Table 4.1.7: Recommended policies for improving the functioning of wheat markets

Aims	**Foster wheat trade**				**Increase self-sufficiency**
Policy measures	**Invest in transport infrastructure**	**Eliminate informal payments**	**Invest in storage facilities**	**Resolve geopolitical conflicts**	**Boost wheat production**
Kyrgyzstan	x	x	x		x
Tajikistan	x	x	x		x
Uzbekistan	x	x	x		x
Armenia				x	x
Azerbaijan					x
Georgia					

Kazakhstan through Azerbaijan, substantially reducing wheat transportation costs.

However, due to large distances to grain producing regions, the grain trade could remain challenged by relatively high trade costs even in more efficient markets with modern transport infrastructure. In addition, the landlocked position of the importing countries leaves little scope for diversification of wheat imports. Also, the Black Sea wheat exporters have a history of restricting wheat exports in times of crisis and the frequency of harvest shortfalls are expected to increase with climate change. Therefore, the countries in Central Asia, but also Armenia and Azerbaijan in the South Caucasus, should complement their trade enhancing policies with agricultural policies aiming to boost domestic wheat production and to increase wheat self-sufficiency. Clapp (2017) discusses the instances when increases in domestic food production makes sense economically and politically to increase food security more broadly, while Watson (2017) provides the contextual analysis of food price policies chosen by the governments in developing countries from the political economy perspective. In the context of Central Asian and South Caucasian wheat markets, we advocate for increased wheat self-sufficiency because of their high trade costs, landlocked geographical location, lack of diversification possibilities of grain imports (especially for Central Asia), and the high importance of food prices for the stability of political systems during the periods of rising bread prices (compare section 2).

Finally, Georgia is the country with the best performing wheat market in these regions by far, resulting from its market-oriented policies and favorable geographic location reflected in lower transportation costs and easy access to the grain export markets in the Black Sea region. Therefore, we see that the food insecurity prevalent in Georgia is not related to a functioning of the wheat markets. Thus, to improve food security in Georgia, more consumer-oriented measures might play an important role.

7 Conclusions

In this paper we investigated wheat price relationships between the six wheat import-dependent countries in Central Asia and the South Caucasus and the three Black Sea wheat exporters to assess how well these markets are functioning. Well-functioning wheat markets ensure availability and access to wheat and are crucial for reducing food insecurity, which is prevalent in countries of Central Asia and the South Caucasus.

Our results summarized in Table 4.1.8 suggest that Georgia is the South Caucasian country with the strongest integrated wheat market, while Uzbekistan is the Central Asian country with the weakest, confirming the findings of Bluashvili and Safaryan (2014), Djuric et al. (2017), and Katsia and Mamardashvili (2016) that grain markets in South Caucasus are well integrated. These results also confirm the findings of Bobokhonov et al. (2017), Ilyasov (2016), and Ilyasov et al. (2016) that grain markets in Central Asia are either segregated (Uzbekistan) or characterized by a lower degree of market integration with the asymmetric structure of price adjustment (Kyrgyzstan and Tajikistan).

Table 4.1.8: Summary of empirical results

	Central Asia			South Caucasus		
	Kyrgyzstan	Tajikistan	Uzbekistan	Armenia	Azerbaijan	Georgia
Market integration						
Black Sea exporters	+	+	+/0	++	++	+++
World wheat markets	+	+	0	++	++	+++
Trade costs						
Black Sea exporters	+	++	0	0	0	0
World wheat markets	0	0	0	0	0	0
Price volatility	++	++	+++	+	+	+

Note: '+' indicates that the analysis provides a positive evidence (+ = moderate, ++ = moderately strong, +++ strong); '0' indicates that the analysis fails to provide a positive evidence.

In addition, our analysis evaluates the functioning of grain markets in a comparative context, providing novel insights into the functioning of grain markets in Central Asia and the South Caucasus. From the comparative analysis it becomes evident that grain markets in the South Caucasus are more strongly integrated with the world wheat market compared to Central Asia. In addition, wheat price volatility is substantially higher in the wheat importing countries of Central Asia compared to the South Caucasus.

Furthermore, our modelling approach has been made evident that trade costs significantly influence grain market integration in Central Asia, while those costs seem to not play a significant role in the integration of wheat markets in the South Caucasus. In particular, wheat trade in Central Asia is characterized not only by higher transportation costs, but informal payments also play a large role.

Weak integration of Central Asia's wheat markets into the world trade system, accompanied by high transportation costs and volatile wheat prices, indicates low resilience of the food system and rather high vulnerability to food insecurity.

Based on those results, we have identified five policy measures for improving the functioning of wheat markets and food security in Central Asia and the South Caucasus.

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APPENDIX

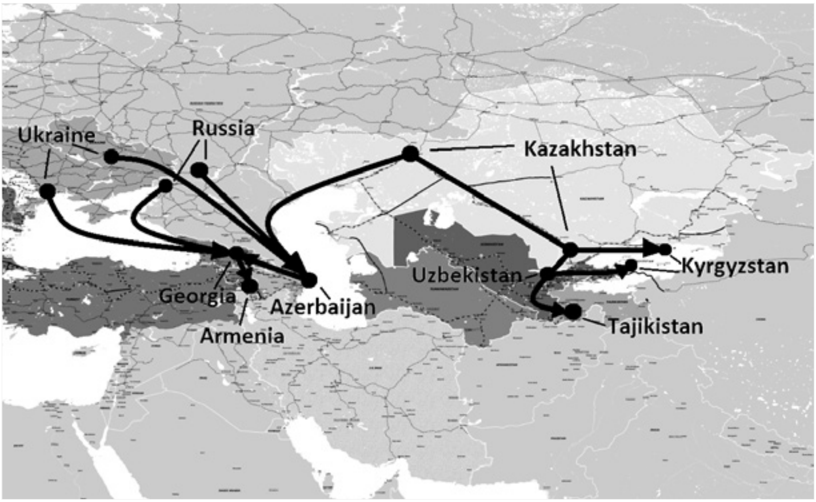

Fig. A.4.1.1: Map of well-established wheat trade routes from the Black Sea region to Central Asia and the South Caucasus

Source: TRACECA (2017), authors' elaboration

Table A.4.1.1: Tests of linear and threshold cointegration

Price series	Engle and Granger test[a]		Hansen and Seo test (1 threshold)[b]
	Test statistic	P-value	P-values
$P_t^{arm} - P_t^{kaz\_n}$	−4.051***	0.001	0.625
$P_t^{arm} - P_t^{rus}$	−3.723***	< 0.001	0.128
$P_t^{arm} - P_t^{ukr}$	−3.614***	< 0.001	0.385
$P_t^{arm} - P_t^{frn}$	−3.545***	0.001	0.114
$P_t^{arm} - P_t^{usa}$	−3.800***	< 0.001	0.796
$P_t^{azn} - P_t^{kaz\_n}$	−3.050***	0.003	0.128
$P_t^{azn} - P_t^{rus}$	−2.731***	0.007	0.251
$P_t^{azn} - P_t^{ukr}$	−2.429**	0.015	0.793
$P_t^{azn} - P_t^{frn}$	−2.674***	0.008	0.817
$P_t^{azn} - P_t^{usa}$	−2.775***	0.006	0.772
$P_t^{geo} - P_t^{kaz\_n}$	−4.783***	< 0.001	0.786
$P_t^{geo} - P_t^{rus}$	−4.123***	< 0.001	0.610
$P_t^{geo} - P_t^{ukr}$	−4.739***	< 0.001	0.234
$P_t^{geo} - P_t^{frn}$	−3.729***	< 0.001	0.670
$P_t^{geo} - P_t^{usa}$	−3.601***	< 0.001	0.568
$P_t^{kyr} - P_t^{kaz\_s}$	−2.893***	0.004	0.021
$P_t^{kyr} - P_t^{rus}$	−2.501	0.327	0.011
$P_t^{kyr} - P_t^{ukr}$	−2.476	0.125	0.451
$P_t^{kyr} - P_t^{frn}$	−2.539**	0.012	0.473
$P_t^{kyr} - P_t^{usa}$	−2.482**	0.013	0.265
$P_t^{taj} - P_t^{kaz\_s}$	−2.972**	0.041	0.033
$P_t^{taj} - P_t^{rus}$	−2.688	0.244	0.020
$P_t^{taj} - P_t^{ukr}$	−2.094	0.248	0.644
$P_t^{taj} - P_t^{frn}$	−2.818***	0.005	0.172
$P_t^{taj} - P_t^{usa}$	−2.902**	0.049	0.595
$P_t^{uzb} - P_t^{kaz\_s}$	−3.904	0.005	0.603
$P_t^{uzb} - P_t^{rus}$	−2.038	0.270	0.909
$P_t^{uzb} - P_t^{ukr}$	−1.526	0.510	0.379
$P_t^{uzb} - P_t^{frn}$	−1.905	0.327	0.786
$P_t^{uzb} - P_t^{usa}$	−1.838	0.357	0.526

Note: [a] H0: no cointegration | H1: linear cointegration. Test is applied to the regression residuals from cointegration equations. One-sided p-values are from MacKinnon (1996). Lag length selection is based on Schwarz Information Criterion. [b] H0: linear cointegration | H1: threshold cointegration. Trimming parameter is equal to 0.05; number of bootstrap replications is set to 1000; fixed regressor bootstrap method. * p<0.10, ** p<0.05, *** p<0.01

5 DISCUSSION, POLICY IMPLICATIONS AND FUTURE RESEARCH

5.1 DISCUSSION OF RESULTS

The United Nations has widely recognized the role international trade can play in achieving the Sustainable Development Goals (SDGs) (UN General Assembly, 2015). In its Agenda 2030, Goal 2 "Zero hunger", which aims to end hunger, achieve food security and improved nutrition and promote sustainable agriculture, affirms to "correct and prevent trade restrictions and distortions in world agricultural markets … [and] adopt measures to ensure the proper functioning of food commodity markets" (p. 16).

The analysis presented in this dissertation as a whole provides evidence on the efficiency of agricultural commodity markets in the post-Soviet countries. With this research, I particularly assess the spatial efficiency of grain markets within Russia and Central Asia and the South Caucasus.

This dissertation contributes to the trade literature by arguing that the spatial efficiency of agricultural markets can affect food security, global and national, in multiple ways. For example, the research has demonstrated that the performance of domestic grain markets in Russia, the largest grain exporting country in the world, can determine the extent to which additional grain production potential is transformed into export potential, having further implications for grain availability on the world market and, hence, future global food security. This thesis also shows that the degree of market integration of import-dependent countries of Central Asia and the South Caucasus into the world market system affects the availability of and access to food from the domestic markets.

Furthermore, this thesis indicates that the 2010/11 grain export ban implemented in Russia resulted in increased market instability and high transaction costs for grain trade within the country. In addition, the results show that a comparative approach enables a more comprehensive assessment of the spatial market efficiency compared to a single country approach. In this regard, some noticeable differences exist between the empirically obtained benchmark estimates and theory-driven values.

In the following paragraphs, I summarize the findings of each contribution briefly but thoroughly, one after another.

Spatial market efficiency of grain markets in Russia

The article of this thesis *"Spatial market efficiency of grain markets in Russia and global food security: A comparison with the USA"* has made evident that the integration of regional grain markets within Russia is relatively low compared to the USA (Fig. 5.1.1: a and b). The results suggest that the degree of regional wheat market integration in Russia is a function of distance to a large extent, respectively characterized by high levels of heterogeneity in its degree of integration. Second, the analysis of the interregional price transmission in Russia has made evident that the Russian wheat market is not uniformly integrated but rather subdivided into two clusters. Especially, the grain production region in the North Caucasus, which primarily exports grain to the world market, is only poorly integrated with the other five large grain production regions, which are mainly involved in domestic grain trade within Russia. This implies that price developments in North Caucasus, which are strongly co-moving with prices on the world market (compare Götz et al., 2016), are only to a limited extent transmitted further to grain production regions of Russia.

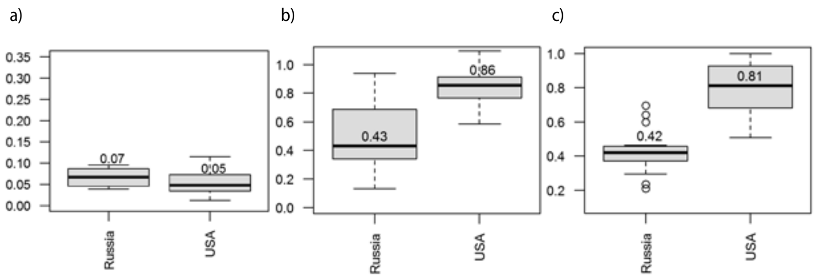

Fig. 5.1.1: Boxplots of the estimated (a) long-run price transmission elasticity parameters, (b) the estimated speed of adjustment parameters and (c) the estimated band of inaction parameters

The results of this study also indicate that trade costs are high in Russia compared to the USA (Fig. 5.1.1: c). Specifically, transaction costs are the highest for the distant grain markets of Ural and West Siberia, explaining their extremely weak integration with the primary grain export region, North Caucasus. This finding has meaningful implications for West Siberia and Ural, which bear large additional grain production potential, accounting for between 25% to 35% of Russia's additional grain production potential of 25 to 65 million tons (Swinnen et al., 2017). However, under current market conditions with a weakly integrated wheat market and high trade costs, the additional wheat production potential in Ural and West Siberia cannot be transformed into additional export potential. Thus, taking these two additional factors into account, Russia's additional grain export potential could increase by at most 15–45 million tons. Further, the results imply that Russia's additional grain export potential falls below the estimated 70 million tons by Deppermann et al. (2018), which assumes that 90% of the additional grain production is transformed into additional grain export.

In the article *"Determinants of spatial market efficiency of grain markets in Russia"*, we are generally interested in studying the factors influencing spatial market integration of the Russian grain markets, again in comparison with the USA. The analysis has made evident that distance is a strong predictor of market integration. At the interregional level, the influence of distance is considerably higher in Russia than in the USA. However, at the intraregional level, the influence of distance is comparable in both of the countries. These results provide evidence for the dissimilarity of the underlying fundamental mechanism of market integration between Russia and the USA.

In Russia, the physical trade of wheat mainly fosters market integration at the interregional level, as wheat is heavily transported not only over small distances, but also over distances up to 4,000 km from production to consumption regions (for example, from West Siberia to the Central region). In contrast, information flows play a rather minor role for the integration of the Russian grain market due to the rudimentary development of futures markets (FAO, 2011). Also, the availability of market and price information based on market monitoring activities by governmental and private agencies is generally low in Russia. Correspondingly, distance has a strong negative influence on market integration at the interregional and intraregional levels in Russia.

Unlike Russia, information flows, in addition to physical trade flows, are of primary importance for market integration at the interregional level in the USA. The efficiency of futures markets and their role in the formation of spot prices explains the relatively small influence of distance on corn market integration in the USA at the interregional level. In contrast, corn is heavily physically traded over small distances within production regions in the USA. For instance, corn consumption industries such as ethanol and livestock facilities, are located around the cornfields. This explains the identified high influence of distance on intraregional market integration in the USA, similar to Russia.

This analysis also indicates that the region in Russia with the largest grain exports (North Caucasus) is less strongly integrated with other regions that are mainly involved in domestic trade, whereas this effect is opposite for the USA. The results also show that the Russian wheat market, in contrast to the US corn market, is characterized by large temporal variations in price transmission elasticities resulting from frequent government interventions and weather-related harvest shortfalls. The results imply that price developments in the wheat markets of Russia are vulnerable to frequently changing governmental policies and weather events.

The influence of the 2010/11 export ban on spatial market efficiency of grain markets in Russia

In the article *"The influence of the 2010/11 export ban on spatial market efficiency of grain markets in Russia"*, results of the price transmission analysis indicate that domestic wheat market integration in Russia strengthened significantly during the export ban period compared to the open trade regime, especially for price pairs including Russia's largest export region North Caucasus (Fig. 5.1.2). This finding could be attributed to the decreased influence of world market conditions on domestic wheat price formations (due to the complete restriction of grain exports) and increased trade flows between regions within Russia (due to the severe harvest shortfalls of up to 60% in some regions and the implemented export ban).

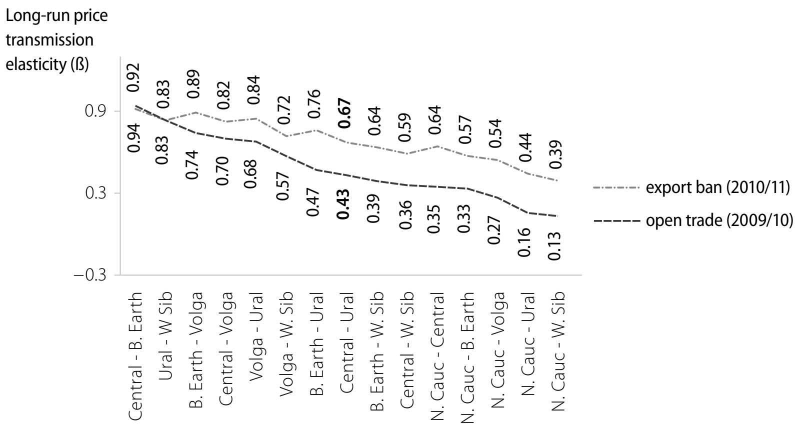

Fig. 5.1.2: The parameters of the long-run price transmission elasticities, 2009/10 and 2010/11

Note: Price pairs on the x-axis are sorted based on the values of price transmission elasticities in 2009/10 in a descending order (from left to right). Median is indicated in bold.

Transaction costs also increased during the export ban period in Russia, traced back to increased transport costs and increased risk of interregional grain transactions. The median upper threshold is about two times higher in 2010/11 (0.04) than in 2009/10 (0.02) and the median lower threshold also increases by 50% during the export ban (0.06) compared to the free trade regime (0.05) (Fig. 5.1.3).

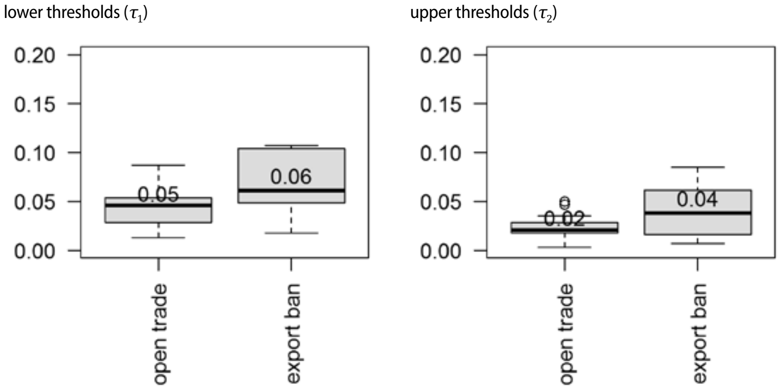

Fig. 5.1.3: Boxplots of the estimated threshold parameters, 2009/10 and 2010/11

Note: Absolute values of the threshold estimates are plotted on the graphs. Plots are based on estimated parameters given in Tables A4 and A5 in the Appendix.

Interestingly, all price pairs that include Ural or West Siberia as a region are characterized by relatively large trade costs in both the restricted and open trade regimes, which can be explained by the peripheral location of these regions and the high transaction costs involved. High trade risk may result from changing trade destinations, which requires involving new trade partners and is associated with a difficulties of contract enforcement. The presence of high transaction costs, on the other hand, contradicts conditions of an efficiently functioning market, which is characterized by low search costs and easy access to information (Aker, 2010).

Functioning of wheat markets in Central Asia and the South Caucasus

The article *"Food security and the functioning of wheat markets in Central Asia and the South Caucasus: A comparative price transmission analysis"* finds evidence of a strong influence of trade costs on market integration in Central Asia, while those costs do not seem to play a significant role in the integration of wheat markets in the South Caucasus. In particular, the wheat trade in Central Asia is characterized not only by higher transportation costs, but informal payments also play a large role. As these results indicate, high trade costs in Central Asia are hindering the efficient functioning of grain markets within the region. The study also finds that wheat price volatility is significantly higher in Central Asia than in the South Caucasus or the Black Sea region (Fig. 5.1.4).

Furthermore, the results suggest that Georgia is the South Caucasian country with the strongest integrated wheat market resulting from its market-oriented policies and favorable geographic location reflected in lower transportation costs and easy access to the grain export markets in the Black Sea region. In contrast, Uzbekistan is the Central Asian country

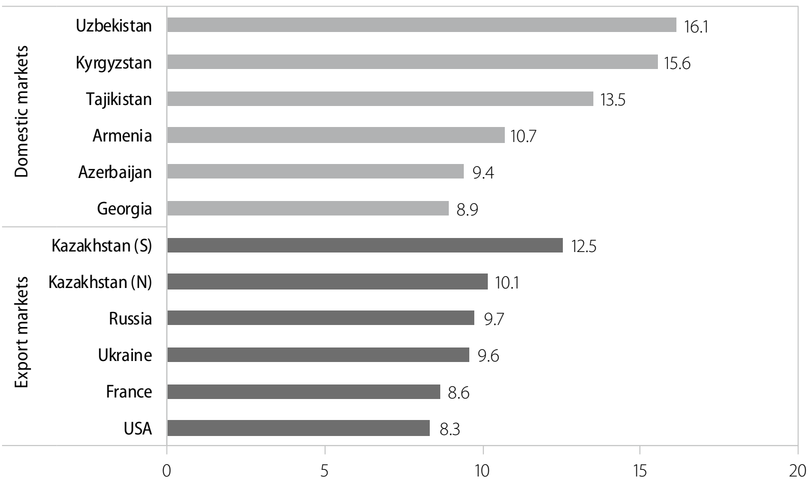

Fig. 5.1.4: Wheat price volatility in wheat importing and exporting countries

Source: See Table 4.1.3

with the least integrated grain markets with a heavy involvement of the government in the wheat production sector and trading.

Weak integration of Central Asia's wheat markets into the world trade system, accompanied by high transportation costs and volatile wheat prices, indicates low resilience of the food system and a rather high vulnerability to food insecurity.

5.2 POLICY IMPLICATIONS

Policy implications for improving spatial wheat market efficiency in Russia

Combining the findings of the studies on the functioning of the Russian grain market, several policy implications in terms of trade policy and food security are offered. These policy implications are aimed at improving the spatial market efficiency of the wheat markets in Russia to ensure the full realization of grain export and production potential, especially in remote areas. By putting the results into perspective, some implications for global food security are also provided.

First, due to long distances and poor infrastructure, distribution of grains between spatially protracted areas can be challenging. As distance influences regional wheat market integration in Russia, *substantial investments in the grain market and transportation infrastructure* are required to improve the integration of domestic markets, especially with the export region.

Nonetheless, the development of trade infrastructure is not sufficient for improving Russian wheat market efficiency since, until now, commodity futures markets are only rudimentarily developed within the country, although they represent an essential aspect of efficiently functioning markets. Without *upgraded market information services and the development of the commodity futures markets,* the spatial market efficiency of grain markets in Russia cannot be improved to a level similar to the corn market of the USA. As another policy measure, the *wheat supply chain could be restructured in marginally located regions.* Livestock production might be taken up in remote grain production regions with excess grain production such as Ural and West Siberia. Instead of exporting wheat to the world market, they might rather export meat profitably to the world market.

The enhancement of the efficiency of Russia's wheat market would ensure the faster transmission of price signals between regions, inducing concomitant flows of trade from surplus to deficit regions. Strengthened integration of domestic wheat markets in Russia and increased price stability would *reduce incentives for the government to implement export controls* on the wheat market as a crisis management policy. As results indicate, the Russian wheat market was also characterized by higher transaction costs during the export ban period, resulting from increased uncertainty and market risk. Increased instability of markets due to recurring governmental interventions discourages investments in grain production, negatively affects further development of the grain sector, and has a detrimental effect on the realization of wheat production potential, resulting in implications for future global food security (Fellmann et al., 2014; Lioubimtseva and Henebry, 2012).

In general, these research contributions studying the spatial market efficiency of the Russian grain market have made evident the importance to *distinguish between agricultural production potential and agricultural export potential,* especially if production potential is located in regions, which are distant to the world markets. Also, this study has shown that to foster global food security, it is not sufficient to focus on raising agricultural production potential e.g. by technological progress in plant breeding and agronomic practices, but also to explicitly *boost agricultural export potential by enhancing spatial market efficiency* in the agricultural sector.

Policy implications for improving spatial wheat market efficiency in Central Asia and the South Caucasus

Based on the results of price transmission analysis, five points of departure for policies to improve the functioning of wheat markets and to raise food security in Central Asia and the South Caucasus are identified (Table 5.2.1).

Table 5.2.1: Recommended policies for improving the functioning of wheat markets

Aims	Foster wheat trade				Increase self-sufficiency
Policy measures	Invest in transport infrastructure	Eliminate informal payments	Invest in storage facilities	Resolve geopolitical conflicts	Boost wheat production
Kyrgyzstan	x	x	x		x
Tajikistan	x	x	x		x
Uzbekistan	x	x	x		x
Armenia				x	x
Azerbaijan					x
Georgia					

By reducing trade costs, the wheat trade between the wheat exporting and wheat importing countries is spurred, which contributes to stabilizing prices and strengthening market integration. *Investments in transport infrastructure,* public or private, are fundamental for reducing transportation costs in Central Asia. In addition, the governments of the Central Asian countries should give priority to *designing and implementing effective policies for eliminating informal payments,* which are another significant factor impacting high transportation costs in the region.

An increase in *domestic wheat storage facilities* in the Central Asian countries, where the wheat storage capacity is less than a week (FEWS NET, 2016), would facilitate managing the wheat price risk and contribute to stabilizing wheat prices and reducing price volatility. Grain stocks could also serve as a crisis measure. For example, strongly increasing wheat prices could be counteracted by releasing grain stocks (Schmitz and Kennedy, 2016).

This empirical analysis has identified that in the South Caucasus, Armenia has the least diversified grain imports and the highest trade costs compared to other neighboring countries in the region. If *Armenia and Azerbaijan would open their closed border* for cargo transiting at least, then Armenia could directly import wheat from Kazakhstan through Azerbaijan, substantially reducing wheat transportation costs.

However, due to large distances to grain producing regions, the grain trade could remain challenged by relatively high trade costs even in more efficient markets with modern transport infrastructure. In addition, the landlocked position of the importing countries leaves little scope for diversification of wheat imports. Also, the Black Sea wheat exporters have a history of restricting wheat exports in times of crisis and the frequency of harvest shortfalls are expected to increase with climate change. Therefore, the countries in Central Asia, but also Armenia and Azerbaijan in the South Caucasus, should complement their trade enhancing policies with agricultural policies aiming to *boost domestic wheat production and to increase wheat self-sufficiency*.

5.3 FUTURE RESEARCH

Beyond the spatial market efficiency of grain markets, assessing the functioning of wheat markets also includes an analysis of wheat price volatility and market power of grain exporters in their export markets. Obviously, this dissertation could not cover every aspect of grain market functioning in the post-Soviet countries, specifically in Russia, in that regard. Since Russia has emerged as the largest wheat exporter in the world and its role within the international wheat export market is expected to increase further, focusing on the functioning of the Russian wheat market is especially important for assessing future global food security. Furthermore, because of Russia's vast potential for grain production, focusing on this country is deemed even more relevant.

The analysis of market power within the Russian grain market

Assessing the competitiveness of Russian grain exporters includes two components: the assessment of price formations in the domestic markets (price relationships at the farmer-trader level) and the international markets (price relationships at the trader-buyer level). While this thesis analyzes the spatial market efficiency of domestic grain markets within Russia, assessing the competitiveness of the Russian grain exporters at the domestic and international markets is beyond the scope of this thesis.

Therefore, the analysis of market functioning can be further extended by examining the price relationships between the domestic and export prices of Russian wheat within the asymmetric price transmission modelling approach. An extensive dataset of domestic and export prices are available from the International Grains Council and the Russian Grain Union. Domestic prices include the quoted prices paid by traders to farmers on the basis of ex-works contracts, while the export prices comprise FOB prices paid to Russian exporters at international markets. Finding evidence for asymmetric price transmission between them could be interpreted as evidence for the existence of a non-competitive market structure, allowing supply chain actors to exert market power (Meyer and von Cramon-Taubadel, 2004).

However, factors other than market power, such as adjustment and menu costs, for example, may also lead to asymmetric price transmission. Therefore, complementing price transmission analysis with theory-driven models that emerged within the New Empirical Industrial Organization (NEIO) could provide additional evidence of the degree of market power in the Russian wheat market. Two major approaches that can be used in the empirical analysis of market power are the

Production-Theoretic Approach (Appelbaum, 1982) and the General Identification Method (Bresnahan, 1982). Perekhozuk et al. (2016) provide a detailed overview of the methods used in the empirical analysis of market power.

Market power in an export market is assessed by examining the pricing strategy of an exporter depending on the exchange rate of different countries. Positive evidence for an imperfect exchange rate pass-through indicates price discrimination in an export market. The existing literature on the analysis of market power of Russian exporters in their destination countries (Gafarova et al., 2015; Pall et al., 2014; Uhl et al., 2016, 2018) finds very little evidence for price discriminating behavior of Russian wheat exporters, concluding that the Russian exporters are rather competitively pricing on the export markets. Furthermore, none of these studies find that Russian exporters exert market power over Egypt, the largest wheat exporting market for Russia (see Fig. 5.3.1). This result is further confirmed by Heigermoser et al. (2018) suggesting that Egypt's GASC tender system[1] creates strong price competition among the world wheat markets.

Nevertheless, the existing literature on the pricing behavior of the Black Sea's exporters covers the period until 2014, i.e., the period with relatively stable exchange rates, followed by a dramatic devaluation of the Russian Ruble starting in November 2014 (Fig. 5.3.2). The year 2014 represents a watershed in the Russian economy. Götz et al. (2015) identify the decline of international oil and gas prices, economic sanctions imposed by western countries, and Russia's responsive ban of agricultural imports from western countries as the causes of the Ruble crisis. Since November 2014, the Central Bank of Russia allowed a fully floating exchange rate regime for the Ruble.

These recent developments of the Russian Ruble exchange rate might have increased the power of Russian wheat farmers (traders) to set the prices in their domestic (export) markets. Therefore, further analysis

1 The General Authority for Supply of Commodities (GASC) is the state procurement organization for food commodities, which continuously purchases wheat on the international markets via a tender system. Roughly 50% of total wheat exports to Egypt are purchased by GASC; the rest is handled by private companies (Heigermoser et al., 2018).

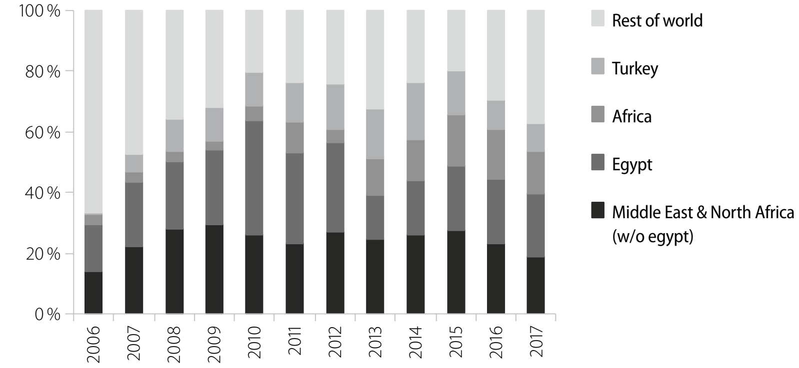

Fig. 5.3.1: Russian wheat export quantities by destination country, 2006–2017

Source: UN Comtrade (2018)

Fig. 5.3.2: Exchange rate: Russian Ruble/USD, daily, 2010–2018

Note: The vertical line marks the date (November 10, 2014) when the Central Bank of Russia moved from a Dollar/Euro currency peg to a fully floating exchange rate regime. Source: CBR (2019) of price relationships between domestic and export Russian wheat prices and the assessment of market power among Russian wheat exporters in their export markets is needed to reexamine whether the pricing behavior of the Russian farmers and traders has changed subsequent to the dramatic Ruble devaluation.

The analysis of wheat price volatility in the Russian wheat market

Exploring wheat price volatility during an era of volatile exchange rates in Russia is another direction for future research. Even though Russia has emerged as a major exporter in the international wheat market and its domestic agricultural markets have also experienced strong turbulences in recent years,[2] the volatility of Russian wheat prices is a study area not yet explored. In contrast, Götz and Jaghdani (2017) have scrutinized the volatility of Russian pork prices along the supply chain within a DCC-MGARCH approach. They find that the volatility of slaughtered pork prices is not driven by the Ruble-USD exchange rate; rather, increased slaughtered pork price volatility coincides with the disintegration of the Russian pork sector with the world pork market (due to the 2014 agricultural import ban). On the other hand, the study finds that the exchange rate does not influence the volatility of domestic pork prices, which may result from the fact that the study focuses on the domestic supply chain (slaughtered pork prices) and includes the period when pork imports were banned in Russia.

Building on this approach, future research on agricultural price volatility may be extended to the Russian wheat markets. It can be expected that the research on Russian wheat price volatility may provide contrasting results compared to Götz and Jaghdani (2017) as wheat exports were

2 For example, the 2010/11 wheat export ban, the 2015 wheat export tax, the 2014 Ruble devaluation, and the 2014 agricultural import ban.

generally freely possible in the post-devaluation period (with the exception of February–May 2015, when the Russian wheat export tax was in place). Moreover, the strong devaluation of the Russian Ruble increased the price competitiveness of Russian wheat exporters on the world wheat market. Therefore, future research of Russian wheat price volatility could address the following research questions: Did the fluctuations in the Russian Ruble influence the volatility of the domestic wheat prices in Russia? Was this effect further passed on to the Russian wheat export prices? In this regard, are there differences between the pre- and post-devaluation periods?

The analysis of spatial market integration between wheat importing countries and the Black Sea exporters

One of the research contributions of this thesis is the analysis of the wheat price relationships between the wheat import-dependent countries in Central Asia and the South Caucasus and the Black Sea wheat exporters in order to assess the wheat market efficiency in these food insecure countries of Central Asia and the South Caucasus.

Apart from Central Asia and the South Caucasus, Russia is also a major exporter to several MENA and African countries (Fig. 5.3.1), whose populations also heavily rely on wheat products in terms of dietary calorie intake (FAOSTAT, 2013). On the other hand, various studies have shown Russia to have good prospects for increased wheat production (Deppermann et al., 2018; Swinnen et al., 2017). It is highly likely that the Russian wheat will be exported to MENA and African countries, as well as to Southeast Asia, as population forecasts imply that the demand for wheat will increase in these regions. In this sense, future research is needed to address the remaining issues concerning market integration in the countries that heavily depend on wheat imports from the Black Sea region and, in particular, from Russia.

Therefore, building on the price transmission analysis conducted for the wheat markets of Central Asia and the South Caucasus, the assessment of spatial market integration between the Black Sea exporters and their important destination countries could be another avenue for future research.

Spatial market efficiency in global scenario studies

This thesis has made evident that the spatial market efficiency of wheat markets in a large export country has implications for global food security and, therefore, it should be included in global modelling scenarios to assess future global food security. However, current modelling efforts within global scenario studies (Le Mouël and Forslund, 2017) assess future production potential based solely on changes in biophysical constraints. In particular, "what-if" scenarios are introduced to assess grain production potential driven by higher grain yields, land use, and climate change effects compared to the baseline situation (Deppermann et al., 2018; Fellmann et al., 2014; Schierhorn et al., 2014; Swinnen et al., 2017). In contrast, spatial constraints, such as the degree of spatial market efficiency associated with large travel distances and trade costs have not been included in the assessment of future grain production potential so far.

Since several large-scale countries beyond Russia are regarded as highly important for future global food security (e.g., Brazil), spatial market efficiency should be given more attention as a further factor determining a country's role in future global food security. Although it is beyond the scope of this thesis, incorporating the econometric results of the analysis of spatial market efficiency into the global scenario studies could provide more realistic estimates of future grain production potential and, hence, contribute to more precise assessments of future global food security.

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ISBN 978-3-95992-096-4

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