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THE RAPID RISE OF RUSSIA'S WHEAT EXPORTS: PRICE FORMATION, SPOT-FUTURES RELATIONS AND VOLATILITY EFFECTS

Maximilian Heigermoser

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 100

Bibliografische Information der Deutschen Bibliothek

Die Deutsche Bibliothek 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 Bibliothek

Die Deutsche Bibliothek 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 rerum politicarum" by the Faculty of Law and Economics at Martin Luther University Halle-Wittenberg on 21.06.2021

Date of oral examination:	17.12.2021
Supervisor and Reviewer:	Prof. Dr. Dr. h.c. Thomas Glauben
Co-Reviewer:	PD Dr. habil. Linde Götz
Co-Reviewer:	Prof. Dr. Ingo Pies

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Theodor-Lieser-Straße 2
06120 Halle (Saale)
Tel.: 49 (345) 2928–0
e-mail: iamo@iamo.de
https://www.iamo.de

ISSN 1436-221X
ISBN 978-3-95992-152-7

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by Maximilian Heigermoser

IAMO 2023

ACKNOWLEDGEMENTS

I would like to cordially thank the three supervisors of this dissertation. PD Dr. habil. Linde Götz for tireless day-to-day supervision, which helped me to greatly strengthen my analytical skills and sharpen my writing. Prof. Dr. Dr. h. c. Thomas Glauben for continued support, as well as numerous fruitful discussions and policy debates. And Prof. Dr. Ingo Pies for valuable comments and suggestions, which helped me to develop new perspectives on my research.

Further, I am grateful to my colleagues at the Leibniz Institute of Agricultural Development in Transition Economies (IAMO) for countless suggestions for improvement of my work, as well as the regular kitchen and hallway conversations that made me enjoy my time at IAMO.

Last but not least, I want to thank my family, my friends and my wife Lysanne. Without your support I would not have been able to complete this work.

SUMMARY

Over the past two decades, the Black Sea region has exhibited significantly growing wheat production and exports. In 2017/18, Russia ultimately became the world's largest wheat exporter, a position that was held by the USA for decades. Mostly serving destination markets in the Middle East and North Africa (MENA) region, Russian grain exports have become vital to ensuring regional and global food security. However, the Russian wheat export market shows several characteristics that can negatively affect agricultural trade, potentially jeopardizing food supply in import-dependent countries. First, in the face of severe harvest shortfalls, Russia and other Black Sea countries have frequently restricted grain exports in the past, which can contribute to price surges on international markets. Secondly, a functioning futures market reflecting Black Sea wheat does not yet exist. Grain traders therefore use established futures markets for price discovery and to hedge price risk in the Black Sea region, which can involve basis risk. Thirdly, previous research has suggested that Russian wheat exporters exercise market power in order to price discriminate among different destination markets. Further, grain exports can be hampered by deficiencies and bottlenecks in the Russian transportation and export infrastructure.

Against this background, this dissertation analyzes how the ascent of Russian wheat exports changes the patterns of global physical trade, results in different pricing dynamics on physical and futures markets, and affects futures price volatility by changing trade policy. The methodological focus lies on time series econometrics, and price analysis in particular. Using vector autoregressive (VAR), autoregressive moving average (ARMA) and vector error correction models (VECM), the econometric analyses are conducted using price series recorded at varying frequencies (monthly to intradaily) to account for economic transactions occurring at different speed on physical compared to futures markets.

An initial, descriptive analysis depicts the evolvement of Russian wheat exports over time, with respect to main destination regions. The focus on Russia's food trade with four key markets in the MENA region, namely Egypt, Turkey, Saudi Arabia and Iran, shows that grain trade is the central component in the respective trade ties. The deepening or loosening of food trade relations corresponds to the present state of respective political ties. Further, a market integration and price leadership analysis is conducted using a multivariate VECM approach. Analyzing the Egyptian wheat tender market as a proxy for the world wheat market, results suggest that European export prices play an increasingly important role for international wheat price formation, likely stemming from close regional proximity between European and Black Sea markets. These results are in line with the findings of a VAR analysis focusing on realized volatility relations between Black Sea spot and leading futures markets. Here, prices posted at the Euronext Paris (EPA) futures market are determined to affect the Black Sea physical market, while such an effect is not found concerning the Chicago Board of Trade (CBoT) market. Further, this analysis provides evidence of asymmetric adjustment to ruble jumps, which suggests that Russian wheat prices are more likely to increase in response to exchange rate movements than they are to decrease. The final ARMA analysis shows that news about Russian grain export restrictions significantly increase intraday seasonally adjusted realized volatility on the CBoT futures market. Further, elevated volatility can be determined in days preceding such news publications. These pre-announcement effects offer important insights into the validity of the Efficient Market Hypothesis (EMH) in the studied market.

The restructuring of the world wheat market resulting from the rise of Russian wheat exports is ongoing. Particularly with respect to futures markets, leading exchanges still compete to establish a functioning Black Sea wheat futures contract that could potentially serve as novel global pricing benchmark. Moreover, the Russian government continues to intervene in the grain trade by imposing export taxes or quotas. Against the background of growing world populations and increased likelihood of harvest shortfalls due to climate change, it is stressed that unimpeded food trade is indispensable to ensure global food security. Policy recommendations aiming to prevent the introduction of food export restrictions are provided at the end of the dissertation.

ZUSAMMENFASSUNG

Über die letzten zwei Jahrzehnte stiegen Weizenproduktion und –exporte in der Schwarzmeerregion bedeutend an. Im Wirtschaftsjahr 2017/18 wurde Russland schließlich zum weltweit größten Weizenexporteur, nachdem die USA diese Position jahrzehntelang innegehabt hatten. Russische Getreideexporte bedienen speziell Märkte in der Region Mittlerer Osten und Nordafrika (MENA) und spielen für regionale und globale Ernährungssicherung eine zentrale Rolle. Allerdings kann der Agrarhandel durch zentrale Spezifika der russischen Weizenmärkte beeinträchtigt und so die Nahrungsmittelversorgung speziell in importabhängigen Staaten gefährdet werden. Erstens reagierte die russische Regierung in der Vergangenheit wiederholt mit Getreideexportbeschränkungen auf gravierende Ernteausfälle, was starke Preissteigerungen auf internationalen Märkten begünstigen kann. Zweitens existiert bisher kein funktionierender Warenterminmarkt, der speziell Schwarzmeerweizenmärkte repräsentiert. Getreidehändler nutzen deshalb etablierte Weizenterminmärkte zur Preisentdeckung und zur Absicherung von Preisrisiken in der Schwarzmeerregion, was jedoch mit Basisrisiko verbunden sein kann. Drittens hat vorangegangene Forschung gezeigt, dass russische Weizenexporteure Marktmacht zur Preisdiskriminierung zwischen verschiedenen Exportmärkten einsetzen können. Ferner können russische Getreideexporte durch unzureichende Transport- und Exportinfrastruktur behindert werden.

Vor diesem Hintergrund analysiert diese Dissertation wie die expandierenden russischen Weizenexporte die Muster des physischen Getreidehandels verändern, zu neuen Preissetzungsdynamiken auf Kassa- und Terminmärkten führen und Preisvolatilität mittels Handelspolitikänderungen beeinflussen. Der methodische Fokus der Arbeit liegt auf Zeitreihenökonometrie und speziell auf Preisanalyse. Unter Verwendung von vector autoregressive (VAR), autoregressive moving average (ARMA) and vector error correction models (VECM) werden ökonometrische Analysen

basierend auf Preisreihen unterschiedlicher Frequenz (monatlich bis intratäglich) durchgeführt. Auf diese Weise findet die unterschiedliche Geschwindigkeit ökonomischer Aktivität auf physischen und Terminmärkten Berücksichtigung.

Zunächst fokussiert eine deskriptive Analyse auf die Entwicklung der russischen Weizenexporte in Hinblick auf verschiedene Exportmärkte. Bezogen auf vier zentrale Importländer der MENA-Region, nämlich Ägypten, Türkei, Saudi Arabien und Iran, machen russische Getreideexporte hier die zentrale Komponente der jeweiligen Handelsbeziehungen aus. Es können ferner Zusammenhänge zwischen der Vertiefung und Abschwächung der Handelsbeziehungen und Veränderungen in den jeweiligen politischen Beziehungen festgestellt werden. Mittels eines multivariaten VECM wird darauffolgend eine Marktintegrations- und Preisführeranalyse durchgeführt, die speziell auf den ägyptischen Weizentendermarkt als Proxy für den Weltweizenmarkt fokussiert. Die Ergebnisse zeigen, dass europäische Exportpreise eine zunehmend wichtige Rolle für die internationale Weizenpreisbildung spielen – wohl auch wegen geographischer Nähe zu den Märkten der Schwarzmeerregion. Diese Ergebnisse stimmen mit denen einer dritten Analyse zur Beziehung zwischen realisierter Volatilität an Kassa- und Terminmärkten überein. An der Euronext Paris (EPA) notierte Preisbewegungen übertragen sich demnach stärker auf die physischen Märkte der Schwarzmeerregion als jene an der Chicagoer Weizenterminbörse (CBoT). Fernere Indizien deuten auf asymmetrische Preisanpassungen nach Jumps im Rubelwechselkurs hin. Russische Weizenpreise steigen demnach in Folge von Wechselkursänderungen eher an, als zu fallen. Eine finale Analyse zeigt, dass Nachrichten zu russischen Getreideexportrestriktionen zu signifikanten Anstiegen der saisonal adjustierten intratäglichen Preisvolatilität an Terminmärkten führen. Erhöhte Volatilität lässt sich zudem an Tagen beobachten, die der Publikation dieser Nachrichten voran gehen. Gerade bezüglich der Validität der Effizienzmarkthypothese sind diese Ergebnisse für den betreffenden Terminmarkt aufschlussreich.

Die Restrukturierung des Weltweizenmarktes, durch den Aufstieg russischer Weizenexporte bedingt, ist mitnichten abgeschlossen. Speziell in Bezug auf Weizenterminmärkte lässt sich konstatieren, dass führende Terminbörsen weiterhin um die Etablierung eines genuinen Schwarzmeerweizenkontraktes, der zur neuen globalen Preis-Benchmark avancieren könnte, konkurrieren. Darüber hinaus setzt auch die russische Regierung ihre Interventionen in den Getreidehandel mittels Exportsteuern und –quoten fort. Vor dem Hintergrund einer wachsenden Weltbevölkerung und steigendem Ernteausfallrisikos infolge des Klimawandels ist uneingeschränkter Nahrungsmittelhandel unerlässlich für die globale Ernährungssicherung. In dieser Hinsicht liefert diese Dissertation schließlich Politikempfehlungen, die darauf abzielen, Nahrungsmittelexportrestriktionen zukünftig zu verhindern.

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LIST OF ABBREVIATIONS

ADF	Augmented Dickey-Fuller (test)
ADM	Archer-Daniels-Midland (company)
AHDB	Agriculture and Horticulture Development Board
AIC	Akaike Information Criterion
AR	Autoregressive (model)
ARFIMA	Autoregressive fractionally integrated moving average (model)
ARMA	Autoregressive moving average (model)
BSW	Black Sea Wheat Futures (ticker symbol of CME's 2012 contract)
BWF	Black Sea Wheat Futures (ticker symbol of CME's 2017 contract)
CBoT	Chicago Board of Trade
CFR	Cost & Freight
CME	Chicago Mercantile Exchange
EAEU	Eurasian Economic Union
ECB	European Central Bank
EMH	Efficient Market Hypothesis
EPA	Euronext Paris
FAO	Food and Agriculture Organization
FOB	Free on Board
GARCH	Generalized Autoregressive Conditional Heteroscedasticity (model)
GASC	General Authority for Supply Commodities
GATT	General Agreement of Tariffs and Trade
GIRF	Generalized Impulse Response Function
HRW	Hard Red Winter (wheat)
HS	Harmonized System (of codes for traded commodities)
ICC	International Chamber of Commerce
IFPRI	International Food Policy Research Institute

IGC	International Grains Council
IRF	Impulse Response Function
ITC	International Trade Centre
KCBoT	Kansas City Board of Trade
KPSS	Kwiatkowski-Phillips-Schmidt-Shin (test)
LOP	Law of One Price
MA	Moving Average (model)
MENA	Middle East and North Africa (region)
MGARCH	Multivariate Generalized Autoregressive Conditional Heteroscedasticity (model)
ML	Maximum Likelihood
MOEX	Moscow Exchange
OAIC	Office Algérien Interprofessionnel des Céréals
OECD	Organization for Economic Co-Operation and Development
OPEC	Organization of Petroleum Exporting Countries
PTA	Preferential Trade Agreement
TMO	Turkish Grain Board
USD	United States Dollar
USDA	United States Department of Agriculture
ROW	Rest of World
RSV	Realized Semi-Variance
RV	Realized Variance
SAGO	Saudi Grains Organization
SDG	Sustainable development goal
SRW	Soft Red Winter (wheat)
STE	State Trading Enterprise
VAR	Vector Autoregressive (Model)
VAR-X	Vector Autoregressive (Model) with Exogenous Variables
VECM	Vector Error Correction Model
WASDE	World Agricultural Supply and Demand Estimates
WTO	World Trade Organization

1 INTRODUCTION

1.1 RUSSIA'S RISING WHEAT EXPORTS: PREREQUISITES AND KEY CHARACTERISTICS[1]

Until the turn of the millennium, the Russian Federation (Russia hereafter) was a net importer of wheat. Less than twenty years later, it became the world's largest wheat exporter for the first time in modern history.[2] Precisely, in season 2017/18 Russian exports amounted to more than 41 million tonnes, which corresponds to 23 percent of world wheat trade and clearly exceeds exports of any other country (Figure 1). Together with Ukraine and Kazakhstan, the three 'Black Sea exporters' recently contribute around one third of total global wheat exports.[3] This development is primarily at the expense of US wheat exports, which decreased from around 26 percent in the early 2000s to about 14 percent in recent years (see also Figure A3). Over the same time horizon, further traditional exporters such as Canada, Argentina and Australia have also lost market shares to the Black Sea exporters, while the EU slightly increased its market share.

Wheat exports from the Black Sea region are of particular importance to global food security. As the world population is projected to grow to around 9.5 billion by 2050 (UN, 2019), global cereal consumption is projected to increase around 2 percent over the next decade, largely due to expected demand growth in Sub-Saharan Africa, India and the Middle East and North Africa[4] (MENA) region (OECD-FAO, 2018).

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1 Parts of this section were published in adapted form in the Russian Analytical Digest (see Heigermoser and Götz, 2019).

2 Russia has also been the world's largest exporter in the Tsarist era in the 19th and early 20th century (Goodwin and Grennes, 1998).

3 The Black Sea region has also become a centre in the physical corn and barley trade. Over the past decade, Ukraine became the fourth-largest corn exporter, accounting for around 20 percent (see Figure A1), while the three Black Sea exporters contribute around 40 percent of global barley exports, which are of minor in volume compared the wheat and corn trade, yet (see Figure A2).

4 The MENA region includes Algeria, Bahrain, Djibouti, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, Syria, Tunisia, Turkey, United Arab Emirates and Yemen.

Particularly in MENA countries, domestic wheat production does not meet consumption due to unfavourable climatic and geographical conditions, resulting in the highest wheat import dependency ratios globally (Sadler and Magnan, 2011). MENA countries further exhibit a high per capita wheat consumption, which is around three times greater than the global average (OECD-FAO, 2020). Food, and particulraly wheat trade is therefore essential to ensure sufficient food supply in the region, particularly in view of the UN's sustainable development goal (SDG) number two of 'zero hunger'.

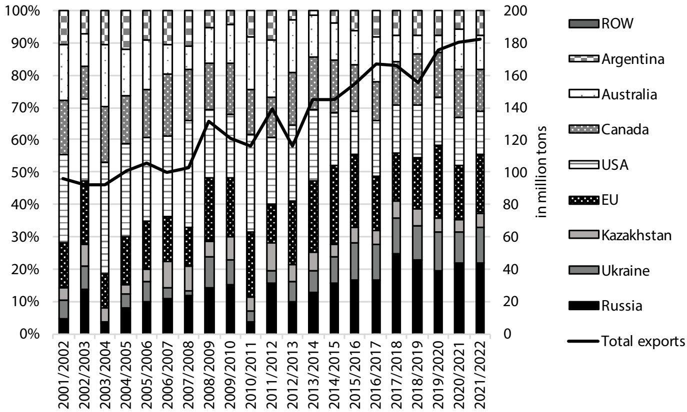

Figure 1: Market shares of world's top eight wheat exporters

Note: Line refers to right y-axis. Values for season 2021/2022 are estimates by the USDA. Top eight exporters are defined based on market shares in season 2021/22.

Source: Own illustration based on USDA (2021).

The MENA region was the uncontested top destination for Russian wheat exports during the 2000s, with Egypt and Turkey alone accounting for around one third of Russia's total exports (Figure 2). Other important destinations in the MENA region are Yemen, Azerbaijan and Iran. However, while around 80 percent of Russian exports headed to MENA countries around the year 2010, this share has declined to less than 50 percent in 2018, as Russia increasingly serves markets in greater geographical distance. Since 2013, demand from Sub-Saharan Africa has increased considerably. Currently, around 20 percent of Russian exports go to this region, where Nigeria, Sudan and Kenya represent the largest importers. More recently, strong growth has also been observed with respect to exports to South and Southeast Asia – especially Bangladesh, Vietnam and Indonesia. Further trade policy adjustments led to additional export opportunities for traders of Russian wheat. In August 2019, Saudi Arabia changed its wheat import requirements to allow Russian wheat to be imported into the country (Reuters, 2019c).[5] Similar adjustments are also continuously discussed in Algeria, which is the world's third-largest wheat importer and currently prohibits the import of Black Sea wheat due to quality concerns (Reuters, 2020a).

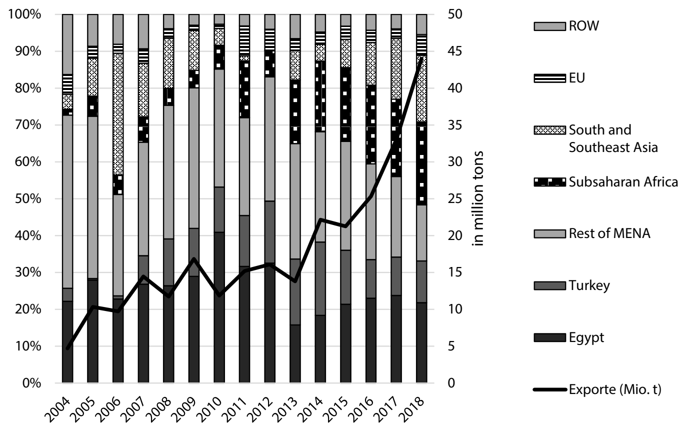

Figure 2: Top destinations for Russian wheat exports

Note: Line refers to right y-axis.

Source: Own illustration based on UN Comtrade (2020)

5 Saudi Arabia is already the largest importer of Russian barley (see section 2.3).

The production and export of wheat in Russia is favoured by several advantageous geographical and geological factors. Russia's agricultural land is vast with 210 million hectare, which compares to 17 million hectares in Germany (World Bank, 2021). Further, Russia's southern, central and Volga regions show highly fertile black earth soils, while climatic conditions also generally favour wheat cultivation in these regions (Schierhorn et al., 2014). Moreover, Russian Black Sea ports, from which most grain is exported, are in geographical proximity to key destination markets in the MENA region, as well as the Suez Canal, which represents the gateway to markets in Asia. This can results in substantial price advantages versus competing exporters due to lower freight costs – a factor that should not be underestimated in agricultural commodities trade (see also Heigermoser and Glauben, 2021).

In recent years, Russian wheat exporters have also benefited from depreciations of the Russian ruble. Particularly in 2014 and 2015, the Russian currency has lost value due to geopolitical tensions and trade sanctions (Glauben et al., 2015). Also falling crude oil or natural gas prices are associated with ruble depreciations, as energy is by far Russia's most important export good.[6] On the world grain markets, a weaker ruble can render pricing advantages to Russian grain exporters versus international competitors. They need to pay less USD to purchase ruble-denoted wheat on domestic markets and can subsequently offer the grain on international markets at lower USD-denoted prices.

Detailed Russian customs data shows that close to 90% of Russia's grain exports flow through ports located at the Black Sea, while smaller quantities are exported by train or via ports at the Caspian Sea, the Baltic Sea or Far Eastern ports (Zerno Online, 2020). Concerning Black Sea exports, the deep-water port[7] of Novorossiysk is the top export facility. Together with Tuapse and Taman, Russia's three deep-water ports handle

6 According to UN Comtrade (2020), energy exports (HS-2 code 27) amounted to around 200 billion USD per year or around 50 percent of Russia's exports between 2016 and 2019. Grain exports (HS-2 code 10) accounted for around 8 billion USD (2 percent) over the same period.

7 Deep-water ports are equipped to handle large supramax and panamax vessels that can load up to 65,000 t of grain.

60% of grain exports shipped via the Black Sea. The remaining 40% are managed by smaller ports located at the Azov Sea and up the Don River, such as Azov, Rostov-at-Don, Taganrog and Yeysk. These shallow water ports handle smaller vessels with capacities reaching up to 25,000 tons. These are particularly important to serve geographically close destination markets such as Turkey, while more distant markets are typically supplied by larger panamax ships (see section 2.2 and 2.3 for details).

Until a decade ago, the expansion of Russian grain exports was impeded by infrastructure deficiencies, which were inherited from the post-Soviet period (Rada et al., 2020). In 2011, the USDA assessed port bottlenecks as the biggest obstacle to increasing Russian grain exports, estimating current Black Sea port capacity at around 25 million tonnes (USDA, 2011). Through commissioning of an additional export terminal at the port of Novorossiysk, this capacity was extended to 28 million tonnes in 2013 (USDA, 2013). Four years later, in season 2017/18, Russia already exported 53 million tons of grain, including 41 million tons of wheat (see Figure 1). Due to additional infrastructure projects, Russia's grain export capacity can be expected to increase further in the future (e.g. World Grain, 2021).

Improvements have also been achieved regarding the modernisation and expansion of grain storage capacity within Russia (USDA, 2017a). This likely contributes to a weakening seasonal pattern, which previously characterized Russia's wheat exports (Figure 3). Prior to 2017, exports were mostly undertaken immediately after the harvest, i.e. in the summer months July to September, before they declined in autumn and reached low points in the winter and spring months (see season 2012/13 in Figure 3, in particular). From 2015/16 onwards, this pattern weakens and exports are distributed more evenly over the marketing year, as storing becomes a more attractive option versus immediate export for Russian farmers and traders. However, while constraints resulting from logistic and infrastructure deficits have eased recently, Russia's novel significance on world wheat markets poses other complications to individual businesses, policy makers and the international food trade system as a whole.

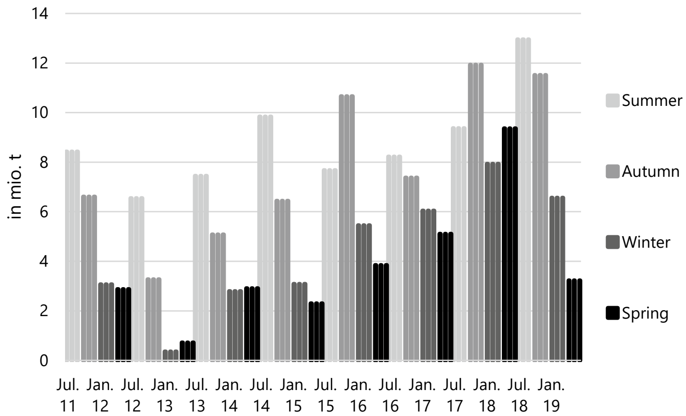

Figure 3: Seasonal patterns in Russian wheat exports

Source: Own illustration based on Zerno online (2020)

1.2 PROBLEM STATEMENT AND RESEARCH QUESTIONS

While climatic conditions generally favour grain production in Russia, extreme weather events also frequently occur in the region (Fellmann et al., 2014, Götz et al., 2016a). In 2010, a severe drought lead to widespread wild fires in key production regions and a subsequent decline of the Russian wheat crop by one third compared with the previous year (Svanidze et al., 2021). Similar harvest losses due to extreme weather conditions were also observed in 2003/04 and 2012/13, leading to diminished exports (see also Figure 1). Facing such harvest shortfalls and subsequently rising food prices, the Russian government has repeatedly restricted grain exports in the past to safeguard national food security. While a dampening domestic price effect of such export restrictions remains doubtful (Djuric and Götz, 2016, Glauben et al., 2015), they certainly jeopardize food security in import-dependent regions. Particularly lower-income countries, where the population spends a large share of income on food, can be severely affected by food exports restrictions that fuel price surges on international markets (Bouët and Laborde, 2016, Mitra and Josling, 2009). In this respect, the Russian export ban on grains in August 2010 is seen as contributing to food price inflation in several import-dependent MENA countries, which catalysed the 'Arab Spring' in 2011 (Bellemare, 2014).

Food export restrictions are often imposed in periods of rising world market prices. Lower supply on international markets can amplify the price increase, especially if other exporters (importers) respond by also increasing (decreasing) their export (import) barriers (Bouët and Laborde, 2016). Such restriction spirals could be observed particularly during the 2006-08 food price crisis (Sharma, 2011), as well as in March 2020 against the background of uncertainty induced by the Covid-19 pandemic (IFPRI, 2021, see also Heigermoser and Glauben, 2020). Therefore, news about export restrictions likely induce uncertainty to the respective market, leading to increased price volatility, which can negatively affect the price discovery and risk management function of futures markets, which typically incorporate new information rapidly due to low transaction costs (Working, 1962). Concerning Russia, as well as Ukraine and Kazakhstan, repeated introduction, adjustment or abolishment of trade barriers has contributed to a general wariness of market participants regrading respective grain trade policy. In effect, 'fear' and 'concern' about trade restrictions reportedly affect market prices even if actual policy changes are not implemented, but only 'rumoured' (see e.g. Financial Times, 2019b, Sowell, 2019).

A functioning Black Sea wheat futures market, which can facilitate risk management and price discovery, does not yet exist for the region. Consequently, market participants rely on traditional futures markets such as the Chicago Board of Trade (CBoT) or the Euronext Paris (EPA), representing US soft red winter (SRW) and French milling wheat, respectively, to manage price risk on Black Sea physical markets. However, futures market prices have to be highly correlated with spot prices to serve as an effective hedging instrument (Vollmer et al., 2021). Regarding the Black Sea region, several factors such as great geographical distance, as well as wheat quality differences can lead to (temporal) divergences between Black Sea spot and futures prices. The resulting basis[8] risk can cause severe financial harm to companies using these futures contracts to hedge Black Sea price risk (see e.g. Financial Times, 2017b). Precisely, losses in the physical market will not be offset by profits in the futures markets (or vice versa) if the basis does not remain constant (Vollmer et al., 2021).

The absence of Black Sea futures markets also lead farmers, traders and processors of wheat to consult alternative sources of information regarding competitive spot price levels from the relatively opaque Black Sea region. In this respect, wheat tenders, which are regularly issued by state procurement agencies of import-dependent countries in the MENA region, play a central role regarding price discovery on Black Sea spot markets. Government agencies from major wheat importers such as Egypt or Algeria (Figure 4) manage between 50% and 90% of imports employing competitive tender systems (see also Table A1). Within regularly issued tenders, numerous trading companies compete to deliver large quantities of wheat from various exporting countries. Competition between companies and between exporting regions drives prices to competitive levels, which are otherwise rarely accessible for Black Sea markets (Reuters, 2012). This gives regional tender prices a high informational value in view of the often opaque supply and demand situation in the Black Sea region. However, while the transparency provided within tender markets allows to assess the degree of market integration between various exporting and key importing regions, the importance of state procurement agencies in international grain trade also points to political relations being a key factor affecting food trade relations with MENA countries.

This dissertation investigates the following, overarching research question: How does the rise of Russian wheat exports affect the world wheat market? Subordinate to this main question, this dissertation will

8 The basis is defined as the difference between a spot and a futures price. If the basis remains constant over time, the respective futures contract can be used to effectively hedge price risk on this spot market (Vollmer et al., 2021).

focus on five specific research questions: First, how can Russia's food trade with key MENA destination markets be characterized? Secondly, how did price formation processes and world market integration change following the ascent of Russian wheat exports? Thirdly, how are Russian spot export prices related to leading futures prices? Fourth, which impact does the ruble exchange rate have on Russian wheat export prices? And fifth, how does news about changes in Russian grain trade policy affect

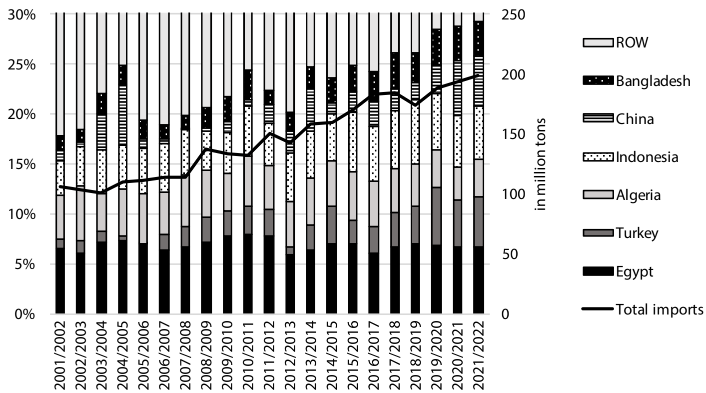

Figure 4: Market shares of world's top six wheat importers

Note: Line refers to right y-axis. Values for season 2021/2022 are estimates by the USDA. Top six importers are defined based on market shares in season 2021/22.

Source: Own illustration based on USDA (2021)

price volatility on futures markets? Corresponding to these questions, the dissertation is divided into four chapters, which are outlined in greater detail in the following section.

1.3 STRUCTURE OF THE DISSERTATION

This dissertation includes one chapter proving a descriptive analysis, as well as three chapters based on econometric time series analyses to assess price level and price volatility dynamics. The descriptive analysis in chapter two provides detailed background information. It traces the development of Russia's exports to specific world regions and then focuses on grain trade with four key trading partners in the MENA region, namely Egypt, Turkey, Saudi Arabia and Iran. While Russia's grain exports are at the center of interest in the analysis, its imports of fruits, nuts and vegetables from the investigated MENA countries are also considered to put the respective trade flows into perspective. The analysis of bidirectional food trade also allows to highlight the political dimension of the considered trade ties. Precisely, chapter two will outline how the establishment or restriction of food trade relations between Russia and the studied MENA countries corresponds to the improvement or deterioration of political relations between the respective partner countries.

Chapter three narrows the focus to Egypt, which is the world's largest wheat importer and also Russia's top destination market. The econometric analysis builds on a unique dataset of transaction-specific import prices observed in wheat tenders issued by the General Authority for Supply Commodities (GASC), the Egyptian state procurement agency for food commodities. As Russia and other Black Sea exporters advanced as major wheat exporters, competitive prices on these opaque markets were "often only coming out in grain tender results" (Reuters, 2012). Therefore, GASC tender prices became a closly watched source of pricing information to the global grains industry. Against this background, chapter three investigates market integration and price formation processes between GASC tender and export prices from the world's top eight wheat exporters using multivariate vector error correction models ($VECM$, Johansen, 1988). Analyzing price linkages at a monthly frequency, this analysis provides a broader view on the position of Russia within global wheat market and further examines price leadership relations for the time period of 2011 through to 2019. The findings are compared with results of previous studies to assess how the rise of the Black Sea exporters has changed pricing dynamics on international wheat markets.

Chapters four and five extend the view to futures markets. In chapter four, price relationships between Black Sea spot and futures prices recorded at the CBoT and the EPA are analyzed. The time series analysis builds on a database of daily Russian export price indices provided by the price reporting agency S&P Global Platts. The spot-futures price relationships are investigated within a vector autoregressive (VAR) model using realized volatility series computed at a weekly frequency as endogenous variables. As previous research has found evidence for imperfect competition in the Russian wheat export sector (Uhl et al., 2016, Pall et al., 2013, Gafarova et al., 2015), asymmetric responses to changes in the ruble exchange rate are further examined by employing realized semi-variances and signed jumps (Patton and Sheppard, 2015). Asymmetric exchange rate pass-through can indicate impefect competition and price discrimination in the Russian grain export sector. This chapter additionally provides insights into ongoing attempts by leading futures exchanges to establish a functioning, genuine Black Sea wheat futures market, which could potentially serve as global wheat pricing benchmark in the future.

Chapter five analyzes a central issue arising from the ascent of Russia's wheat exports, namely the risk of grain export restrictions. It analyzes the effect of news reports about Russian grain trade policy on price volatility observed at the CBoT, which is the most liquid wheat futures market, playing a key role for global wheat price discovery (Janzen and Adjemian, 2017). Using high-frequency futures price data (Tick Data, 2020) and news reports from the Russian news agency Interfax (Nexis Uni, 2020), various daily volatility measures are estimated from intraday price returns. Including event indicator variables in a seasonally adjusted autoregressive moving average $(ARMA)$ model, the effect of news regarding Russian grain export restrictions are compared to volatility responses to World Agricultural Supply and Demand Estimates (WASDE), which are published by the United States Department of Agriculture (USDA). Aside from quantifying direct announcement effects, the usage of this methodology further enables the examination of pre-announcement effects over an extended period and generates valuable insights into the validity of the Efficient Market Hypothesis (EMH) regarding the studied market. This chapter further provides a comprehensive, detailed overview of Russia's imposed grain export restrictions after 2015, while also presenting details on restrictions that were discussed or planned, yet not implemented.

In the concluding sixth chapter, the results are summarized, and potential research topics arising from the research results are proposed. Moreover, limitations of the conducted analyses are discussed and business implications and policy recommendations are weighed. Finally, section 6.4 provides an outlook.

2 RUSSIA'S FOOD TRADE RELATION WITH SELECTED MENA COUNTRIES[9]

9 A largely congruent version of this chapter was published as a book section in the anthology "Russia's Role in the Contemporary International Agri-Food Trade System" edited by Stephen Wegren and Frode Nilssen (see Heigermoser et al., 2021a).

Russia's food exports[10] started to increase substantially with the turn of the millennium. Between 2011 and 2019, Russia's total food exports more than doubled from 11 billion USD to 24 billion USD (see Figure 5), while it is the government's declared objective to further increase the volume of food exports to 45 billion USD by the year 2024 (Wegren, 2020). Simultaneously, Russia's food imports have strongly decreased. A particularly sharp decline can be observed from 2014 to 2015, when imports fell by almost a third from 39 billion USD to 27 billion USD. This decrease results from Russia's decision to implement a complete ban on agricultural imports from western countries in August 2014 (Liefert and Liefert, 2015, Wegren, 2014, Banse et al., 2019). As Russia's food exports grew in the 2000s, the MENA region became Russia's most important destination region, particularly for grain exports, as around one third of Russia's food exports were destined for MENA countries in 2019 (see Figure 5).

Russia's primary agricultural export item is grains, which accounted for 37% of the country's food exports between 2011 and 2019 (UN Comtrade, 2020). Among grain exports, wheat is most important, accounting for more than 75%, followed by barley (11%) and maize (11%). The MENA region is Russia's top market for grain exports. Due to unfavourable climatic conditions, only 70% of grain consumed in MENA countries is produced domestically (USDA, 2021), while the rest – 90 million tons annually – is imported, with Russia and further Black Sea exporters playing a key role. This chapter primarily focuses on Russia's wheat exports to the MENA region, while barley, maize and sunflower oil exports are considered in specific cases. To put the exports into perspective, we further shed light on Russia's food imports from MENA countries, which mostly consist of fruit, nuts, and vegetables.

10 In the following, all products falling under the two-digit HS codes 01 through 23 are defined as food products. The trade statistics are presented as provided by the Russia to the UN Comtrade database.

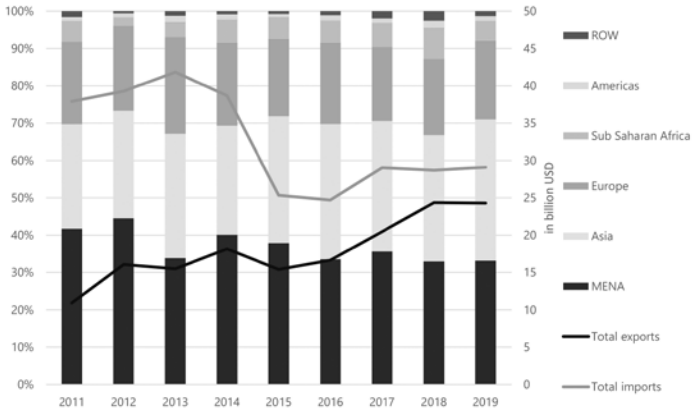

Figure 5: Top destinations for Russian food exports

Note: Lines refers to right y-axis. All food products encompassing two-digit HS-2 codes 01 through 23 are considered. The trade volumes are presented as reported by Russia to the UN Comtrade database.

Source: Own illustration based on UN Comtrade (2020).

We focus on four key destination markets within the MENA region, namely Egypt, Turkey, Saudi Arabia, and Iran (Table 1). Jointly, these four countries accounted for close to two-thirds of Russia's food exports to the whole region between 2011 and 2019, while 55% of Russia's food imports from MENA originate from these three countries (UN Comtrade, 2020). Grain is the main commodity of this food trade relationship. Egypt and Turkey are the two top wheat export markets for Russia, while Saudi Arabia is the primary destination for Russian barley exports. The food trade is largely unidirectional considering Egypt and especially Saudi Arabia, while Turkey is also a significant supplier of fruit and vegetables to Russia (Table 1). Considering Russia's total food exports, Turkey is the most important destination market followed by China and Egypt, while Saudi Arabia falls into the top ten. Regarding Russia's most important suppliers of food, Turkey is fifth, trailing Belarus, Brazil, China and Germany.

Table 1: General statistics about Egypt, Turkey, Iran and Saudi Arabia

	Turkey	Egypt	Iran	Saudi Arabia
Total Population in 2019[a]	83 million	100 million	83 million	34 million
Per capita wheat consumption in 2020[b]	209 kg/year	190 kg/year	168 kg/year	101 kg/year
Total annual imports, in million tons, 2015-20 average[c]				
wheat	6.9	12.4	0.9	3.4
maize	2.6	9.8	8.9	3.9
barley	0.5	0.1	2.6	7.4
Self-sufficiency ratios, 2015-20[c]				
wheat	98%	42%	92%	4%
maize	70%	39%	12%	2%
barley	93%	--	57%	0%
State procurement agency	Turkish Grain Board (TMO)	General Authority for Supply of Commodities (GASC)	State Livestock Affairs Logistics (SLAL), Government Trading Corporation of Iran (GTC)	Saudi Grains Organization (SAGO)
Food imports from Russia, average 2017-19[d]	2 billion USD	1.8 billion USD	0.85 billion USD	0.39 billion USD
Food exports to Russia, average 2017-19[d]	1.15 billion USD	0.4 billion USD	0.47 billion USD	0.00 billion USD
Share of agricultural trade within total trade with Russia, 2017-19[d]	13%	32%	66%	33%

Source: Own illustration based on: [a] World Bank (2020). [b] OECD-FAO (2020). [c] USDA (2021a). [d] UN Comtrade (2020)

In most MENA countries, state trading enterprises (STEs) play a crucial role regarding food commodity imports (Ahmed et al., 2013, Ghoneim, 2015). In most instances, the respective STEs have a dominant, if not monopolistic position, as primary or exclusive importers of grain. The Egyptian General Authority for Supply Commodities (GASC), the Turkish Grain Board (TMO) and the Saudi Grains Organisation (SAGO) manage 49 percent, 73 percent, and 91 percent of imports, respectively (see also Table A1 in the appendix). Further, the Russian food trade with MENA countries and the respective STEs is frequently impacted by conflicts about product quality and disputes about compliance to phytosanitary standards. More generally, political tensions or rapprochements between the respective countries appear to affect the respective food trade relations (Wegren et al., 2016a, Wegren et al. 2016b). Focusing on these key aspects, the following four sections provide detailed descriptive analyses of the food trade relations between Russia and Egypt, Turkey, Saudi Arabia and Iran, respectively.

2.1 EGYPT

Egypt is the world's largest wheat importer and the top destination for Russian wheat exports. The North African country buys around 12 million tons per season, as its domestic production only covers around 42% of total consumption (IGC, 2020). Around half of Egypt's wheat imports are handled by the GASC, a STE responsible for the procurement of food commodities. In fulfilling its mandate, the GASC alone imports as much wheat as the whole of Japan, making the agency a key single player on the international market (McKee, 2013). To purchase wheat, as well as other food commodities such as rice, soy oil or sunflower oil, the agency employs a tender system. The purchased wheat is processed domestically to produce baladi flat bread. This staple food is sold at subsidised prices to Egyptians with lower incomes (Heigermoser, 2017). Egypt's bread subsidy program is a politically sensitive issue and efforts to abolish or reform the subsidy system have resulted in uprisings and riots in the past (Ghoneim, 2015). Since season 2015/16, Russia is the uncontested top supplier of wheat to the GASC (see also section 3.1).

Russia exports significant amounts of wheat and sunflower oil to Egypt and imports fruits and vegetables from the North African country (Figure 6). However, food trade between the two countries has repeatedly been affected by conflicts over product quality and compliance with phytosanitary standards. A major Russo-Egyptian food trade dispute arose after Egypt imposed a zero-tolerance policy regime regarding ergot contamination[11] in wheat cargos shipped to the GASC on August 28, 2016. After declaring that wheat shipped to the GASC must contain zero ergot – which is practically impossible for traders to ensure when wheat is delivered in bulk – Egypt rejected cargos from Romania and Russia in early September 2016, as they failed to meet the newly established quality standards (Financial Times, 2016). In response, wheat traders boycotted subsequent wheat tenders that the GASC had to cancel due to a lack of offers. On September 16th 2016, the Russian government announced that fruit and vegetable imports from Egypt would be temporarily halted starting September 22nd, due to concerns over food safety. Shortly after, on September 21st, the Egyptian government decided to cancel the zero-tolerance ergot policy (Reuters, 2016a). This was followed by the resumption of fruit and vegetable imports from Egypt to Russia on September 26th. Importantly, however, the resumption of food imports did not include Egyptian potatoes – its second most important export to the Russian market after citrus fruits – which remained banned from entry to the Russian market until December 14th. Russia itself is a large producer of potatoes and could become a net exporter in the future after becoming virtually self-sufficient in potato production recently (USDA, 2020b).

In a similar trade dispute, several shipments of Egyptian potatoes were initially rejected at Russian ports in March and May 2018 due to alleged infestations with brown rot disease (Enterprise Press, 2018). On May 31st 2018, Egyptian officials rejected a cargo of Russian wheat because it exhibited ergot contamination levels of 0.06 percent, exceeding the acceptable level of 0.05 percent (Reuters, 2018c). Two days after the

11 The common ergot fungus often infests wheat crops and causes harm to humans if it is consumed in large quantities. However, small amounts of ergot are harmless, and the international trade considers ergot levels in wheat of less than 0.05 percent acceptable.

rejection of the cargo, the Russian government announced that potato imports from specific Egyptian regions, which had previously been banned would resume on June 6th. Conducting a second test on ergot levels of the respective Russian wheat cargo, Egyptian officials concluded that the wheat contained 0.01 percent ergot and was therefore allowed to enter the country. However, even as potato exports to Russia resumed, the potato trade volume still declined from 120 million USD annually in 2014 through 2018 to 60 million USD in 2019 (Figure 6). While adjustments in trade policy and phytosanitary standards by the Egyptian and Russian governments are usually not explicitly implemented as a response or in retaliation to steps taken by the other side, the sequence of policy changes displayed above suggests that the food trade between the two countries is shaped by political considerations.

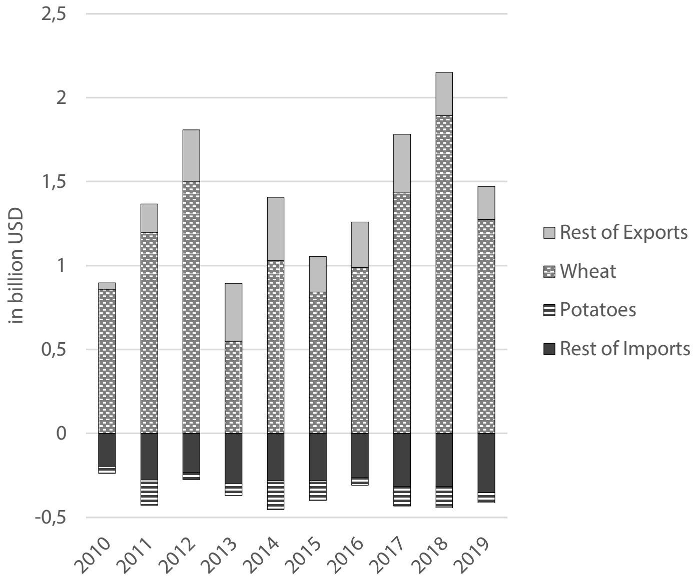

Figure 6: Russia's food trade with Egypt

Note: Russian exports are depicted above, Russian imports below the x-axis.
Source: Own illustration, based on UN Comtrade 2020.

In 2017, several reports published by Reuters portrayed widespread corruption in the Egyptian food procurement system, with government officials allegedly taking bribes in order to guarantee seamless passage of imports into Egypt (Reuters, 2017b). While the effort to curb corruption resulted in arrests of several responsible government officials, disputes over ergot levels and adjustments to the quality inspection procedures continue to cause friction. However, it can be expected that Russia will remain the uncontested top supplier of wheat to Egypt due to its competitively priced wheat and freight cost advantages over competing origins such as the USA or France.

2.2 TURKEY

Turkey is Russia's most important trading partner in the MENA region with an average annual food trade volume of 3.15 billion USD between 2017 and 2019 (Table 1). Food trade, however, constituted only 13% of total trade between the two countries over the past decade. Turkey – a country dependent on energy imports – predominantly imports natural gas and crude oil from Russia, making energy trade the prior component in the economic relationship between the two countries bordering the Black Sea. Turkey is mostly self-sufficient in wheat and barley production, while total corn consumption exceeds domestic production by around 40% (IGC, 2020). However, grains and wheat in particular still account for more than 55% of Turkey's food imports from Russia (Figure 7). Excess quantities are processed into wheat flour, which Turkey exports foremost to Iraq, as well as Syria and Yemen. With a world market share of 20% and exports worth one billion USD per year, Turkey is the world's largest wheat flour exporter, followed by Kazakhstan (10.5%) and Germany (6.5%, UN Comtrade, 2020).

Similar to Egypt, Turkey's grain imports are managed by an STE, the Turkish Grain Board (TMO). The TMO covers Turkey's wheat and feed corn imports and also purchases feed barley if domestic production does not meet consumption. While the TMO, like its Egyptian counterpart, predominantly purchases Russian wheat, it sources grain from smaller Russian shallow water ports located at the Azov Sea and up the Don River, most notably the ports Azov and Rostov-on-Don. Shipping grain using large panamax vessels enables economies of scale if geographically distant destination markets are supplied. Turkey, however, is located in close geographical proximity to the Russian grain export facilities. The TMO therefore purchases numerous smaller parcels of between 10,000 and 30,000 tons in its grain tenders. Grain exports from Russia's shallow water ports show particularly strong seasonality patterns as some port facilities become inoperable in the winter months due to cold temperatures (Zerno Online, 2020, see also Heigermoser and Götz, 2019).

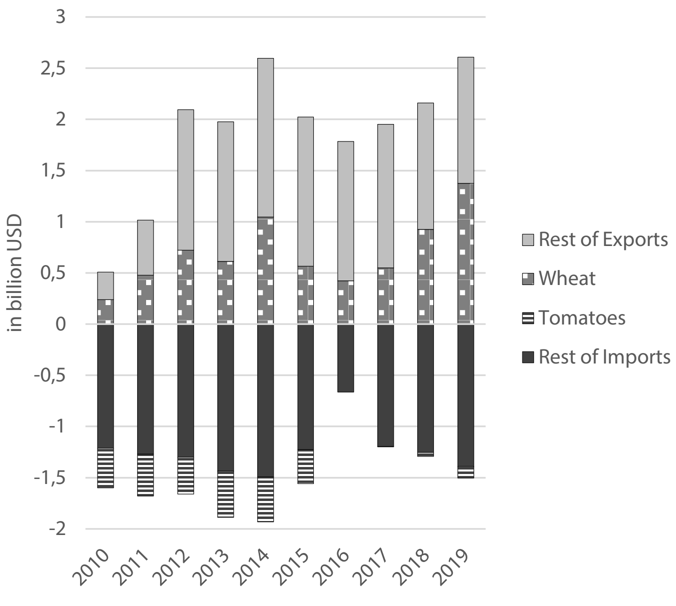

Figure 7: Russia's food trade with Turkey

Note: Russian exports are depicted above, Russian imports below the x-axis.

Source: Own illustration based on UN Comtrade (2020).

Despite the strong economic entanglement between Russia and Turkey, the bilateral food trade was highly affected by political tensions between the two countries in recent years (Önis and Yilmaz, 2016). On November 24, 2015, a Russian fighter jet operating in Syria was downed by the Turkish military close to the country's border. In response, Russia introduced an extensive package of sanctions against Turkey, including a ban on imports of Turkish food products such as tomatoes, onions, cucumbers, grapes, apricots, apples, chicken products and salt, while imports of lemons and nuts remained unrestricted just like the energy trade that is central to the bilateral trade relationship (Reuters, 2015). After these trade restrictions took effect on January 1st, 2016, the Kremlin announced in late June 2016 that Ankara had apologised for downing the military jet. Subsequently, after a meeting between the two countries' presidents in St. Petersburg in early August 2016, the intent to 'normalise' the bilateral relationship and a gradual lifting of the Russian import restrictions were announced (Reuters, 2016e).

As a consequence of the implemented trade restrictions, Russia's food imports from Turkey decreased by more than 50%, from 1.5 billion USD per year between 2011 and 2015 to 663 million USD in 2016 (Figure 7). Conversely, Russian food exports to Turkey only showed a modest decrease of around 15% in 2016. After the agreement to gradually resume food trade in late 2016, Russia's food imports from Turkey rebounded to around 1.25 billion USD per year in 2017 through 2019, still standing below the levels recorded prior to 2016. This gap in trade volume is almost entirely resulting from diminished imports of Turkish tomatoes, which remained restricted after 2016. Exempting tomatoes from the resumption of food trade corresponds to an effort by the Russian government to support domestic tomato production to ultimately reach self-sufficiency. Indeed, Russian vegetable greenhouse production grew by around 12% annually over the past five years (IKAR, 2020).

As Russia's ban on Turkish tomato imports remained in place, Turkey removed Russian food products, most notably wheat, corn and sunflower oil, from its tax-free import licence list on March 15, 2017, which effectively barred all Russian food exports to Turkey (Reuters, 2017c). Following another meeting between the state leaders in Sochi, Russian food exports to Turkey resumed in May 2017. However, the ban on Turkish tomatoes was only partially relaxed and converted to an import quota that came into effect on November 1, 2017 (Azer News, 2017). This new policy regime allowed only a small number of Turkish companies to sell tomatoes to Russia, which prompted Ankara to threaten a similar limitation on the number of Russian companies accepted to ship food products to Turkey on March 19, 2018 (Hurriyet Daily News, 2018). In late April 2018, the limitation of the number of trading companies allowed to sell tomatoes to Russia was finally removed, while the import quota remained unchanged until March 28th, 2019, when a tripling of the quota to 150,000 tons was announced. This policy adjustment followed an announcement by the Turkish government to implement a 5,000 ton tax-free import quota per year for beef imports from Russia.[12] A further increase of the Russian import quota to 200,000 tons was announced on February 26, 2020 and a complete abolishment reported to be discussed in mid-July 2020. However, as Turkish tomato exports to Russia amounted to around 340,000 tons per year before 2016 and in light of Russia's expansion of greenhouse vegetable production over the past five years, a further increase or abolishment of the import quota is likely to have little effect on Turkey's tomato exports to Russia.

2.3 SAUDI ARABIA

Until 2016, the food trade between Russia and Saudi Arabia was limited to Russian barley exports (Figure 8). For several decades, Saudi Arabia has been the world's largest barley importer with annual imports of around 7.5 million tons and a market share of around 30%.[13] Today, Saudi Arabia is entirely dependent on the import of barley, which is used as animal

12 It must be noted that Russia remains a net exporter of beef and exports only very small quantities of beef so far.

13 Most recently, China's barley imports have increased substantially and have exceeded Saudi Arabian barley imports, particularly in 2015 (UN Comtrade, 2020).

feed in the country. Since the early 2000s, Saudi Arabia sources around 40% of its barley from the Black Sea region, primarily from Ukraine, followed by Russia. In particular years, the Black Sea market share has even exceeded 60%. While Saudi Arabia is still the top destination for Russian barley exports, its share has decreased from 60% between 2011 and 2015 to 40% since 2016, while exports to other MENA countries, particularly Iran and Jordan increased substantially (UN Comtrade, 2020).

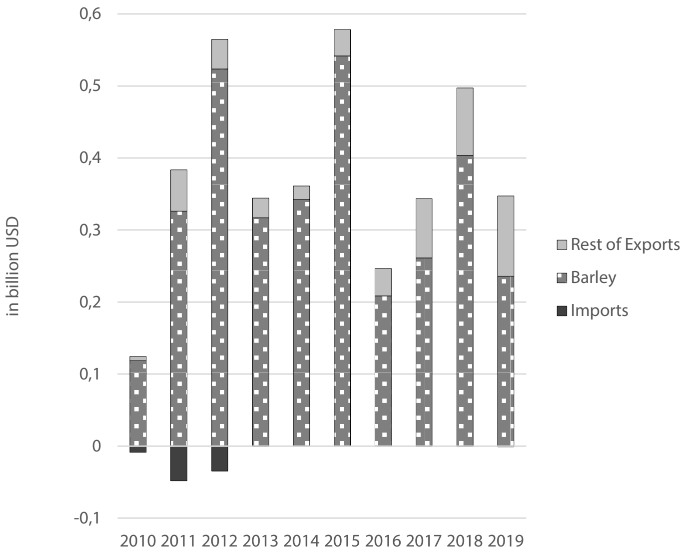

Figure 8: Russia's food trade with Saudi Arabia

Note: Russian exports are depicted above, Russian imports below the x-axis.

Source: Own illustration based on UN Comtrade (2020).

Currently, Saudi Arabia is also among the top 20 wheat importers. However, the country only started importing grain on a larger scale in 2008. In the early 1980s, Saudi Arabia had formulated an extensive self-sufficiency policy encouraging and supporting domestic wheat production projects, which were entirely based on irrigation (Grindle et al., 2015, Lippmann, 2010). This policy enabled the country to indeed become a sizeable wheat exporter between 1985 and 1994 (USDA, 2021a), before the domestic wheat production was scaled back to only supply the domestic market. Due to serious concerns about depleting water reserves, the irrigation-intensive wheat production was gradually phased out between 2007 and 2016. During this time period, Saudi Arabia's wheat imports increased steadily to ultimately reach 3.4 million tons annually. In November 2015, the Saudi Grains Organization (SAGO) was established to manage the country's grain imports (USDA, 2017b). The SAGO has a monopoly on the import of milling wheat and is responsible for the vast barley imports, as well. Feed corn, of which Saudi Arabia is also a major importer, is imported by private companies. Similar to the countries discussed previously, the SAGO employs a tender system to purchase grains on the international market. Compared to its counterparts in Egypt and Turkey, the SAGO issues tenders rather infrequently (i.e. roughly every two months), then buying large quantities at once.

After years of bilateral negotiations, Russian wheat was approved to be offered in SAGO tenders on August 8, 2019 (Reuters, 2019c). Precisely, tolerated bug damage levels for Russian wheat were adjusted from a practically prohibitive 0% level to a manageable level of 0.5%. The decision was announced after samples of Russian wheat were sent to Saudi Arabia in late 2018 and multiple meetings between government officials had taken place to discuss amending the quality specification. Previously, Russian wheat has been allowed to enter the country. However, a Russian wheat cargo exhibiting strong contamination with the sunn pest on arrival prompted the government to effectively ban Russian wheat in 2012 (Bloomberg, 2017). Following the re-approval, the first two cargos of Russian wheat purchased in SAGO tenders were sent to Saudi Arabia in April and May 2020.[14]

14 An increasing share of Russian wheat in the Saudi Arabian market could negatively affect exporters from Germany and the Baltic states, which were previously the top suppliers of wheat to Saudi Arabia.

The opening of the Saudi Arabian market for Russian wheat must be seen in the context of a steadily improving relationship between the two countries in recent years. After bilateral relations reached a low point due to opposing involvements in the Syrian civil war, Saudi Arabia and Russia, the two largest crude oil exporters worldwide, initially started to cooperate in oil markets in 2016 in view of crude oil prices falling to historic low levels (Reuters, 2016d). An agreement to cut oil production within the Organization of Petroleum Exporting Countries (OPEC) was signed on December 10, 2016, resulting in rising oil prices in the following years. Similarly, food exports from Russia to Saudi Arabia, which had halved from around 500 million USD annually in 2012 through 2015 to 250 million USD in 2016, returned to previous levels (Figure 8). Additionally, since 2016, Russia's food exports to Saudi Arabia show a gradual diversification, as cocoa products, as well as poultry, started to be exported to Saudi Arabia in 2017 and 2018, respectively. This resulted in a decreasing share of barley in total food exports from 95% in 2014 to 68% in 2019.

On October 14, 2019, during the first state visit by the Russian president Vladimir Putin to Riyadh since 2007, the heads of state signed a comprehensive memorandum of understanding (MoU) aiming to further improve the bilateral relationship. Alongside various agreements on joint investments and expanded cooperation, both governments reaffirmed their intent to increase the mutual food trade. Particularly, the Russian side expressed interest in the export of animal and dairy products, among others, while Saudi Arabia proclaimed the intent to export fish and shrimp products, as well as fruit and dates to Russia (Interfax, 2019). During a preceding bilateral meeting in early September 2019, the Russian Minister for Agriculture had underlined the goal of quadrupling Russian food exports to Saudi Arabia to reach two billion USD in 2024 (Reuters, 2019e). The MoU should be seen in the context of Russia's ambitious goal to increase food exports to 45 billion USD by 2024 (Wegren, 2020).

2.4 IRAN

After the collapse of the Soviet Union, there was a bilateral political will to expand trade relations between the Russian Federation and the Islamic Republic of Iran (hereafter: Iran). The 'Look to the East' policy defined by Tehran in 2006 (Adami, 2010), promoted the improvement of Iran's economic and political relations with Russia and China after many years of a no-alliance policy (Tarock, 2017). While the respective bilateral economic relationships remain insignificant if total trade is considered, agricultural and food trade has increased substantially since 2017 (Figure 9). In 2018, Iran had imported food products worth 856 million USD from Russia, while food exports to Russia showed a volume of 450 million USD.[15] As such, food trade accounted for around two-thirds of the total Russo-Iranian trade between 2017 and 2019. Russia and Iran both have large oil and natural gas reservoirs, and both rely on fossil fuel exports. However, Iran has an arid to semi-arid climate and is confronted with severe water scarcity issues. Despite this fact, Iran has implemented self-sufficiency policies, particularly for its domestic grain production, which is affected by varying levels of precipitation. As Russia turned into a major grain exporter, Iran has started to diversify its grain import portfolio by relying more on Russia, while imports from other countries remain substantial, as well (ITC, 2020, Lim, 2020). In 2018, maize was Iran's primary food import from Russia followed by sunflower oil and barley. The top food exports from Iran to Russia are fruit, nuts and vegetables. It must be added that there is a volatile pattern of Iranian wheat imports from Russia, which mainly depends on the domestic wheat production in Iran and thus on annual precipitation levels.[16]

15 The data available in Iranian sources presents different trade volumes compared to data provided by the UN Comtrade Database. Following these sources, Iran has imported 661 million USD agricultural and food products from Russia and exported 218 million USD of the same commodity groups to Russia (AWNRC, 2019).

16 Recently, plans to import Russian wheat to Iran to process it into flour for re-exporting to Iraq have been formulated. However, so far, such activity, which would put Iranian flour producers in competition with Turkish producers on the Iraqi market, has not yet materialised.

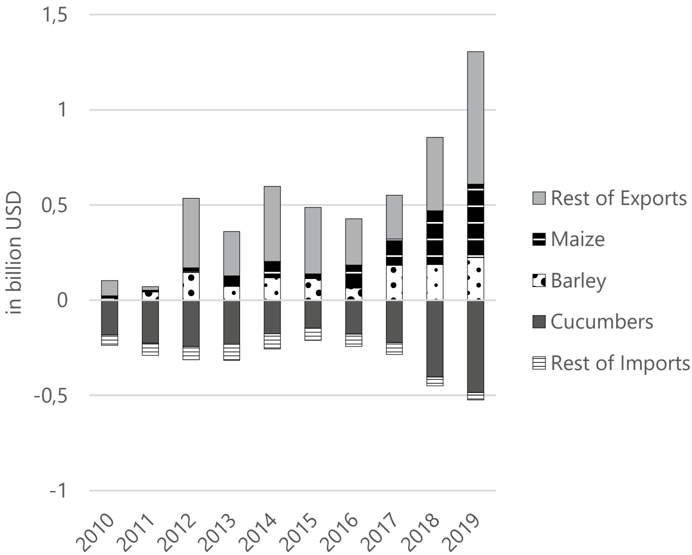

Figure 9: Russia's food trade with Iran

Note: Russian exports are depicted above, Russian imports below the x-axis.
Source: Own illustration based on UN Comtrade (2020)

While Russia and Iran do not have a land border, both countries border the Caspian Sea. The food trade over the Caspian Sea is mainly conducted via the Russian port of Astrakhan and the ports of Amirabad and Anzali in Iran (Zerno Online, 2020). However, the bilateral seaborne trade is impeded by a lack of adequate infrastructure, as well as bureaucratic hurdles. For instance, the available port facilities are not well prepared to handle container trade and to store fresh agricultural produce (Kuzehgarkaleji, 2020a). Furthermore, non-Russian vessels are only allowed to use Russian inland waterways after paying a fee of 30,000 USD. As this fee is essentially prohibitive, non-Russian vessels need to either unload cargos at the ports of Astrakhan or Makhachkala or switch to Russian vessels (Kuzehgarkaleji, 2020b). Facing these impediments, a mutual protocol aimed at the improvement of trade infrastructure and the reduction of bureaucratic hurdles was signed in 2019 (Mehr News

Agency, 2019). Furthermore, the first permanent container shipping line between Iran and Russia is planned to be established in September 2020, which could increase the trade of fresh food products (Tejaratgardan, 2020). Further reports have announced the construction of additional Russian port infrastructure in Lagan at the Caspian Sea, which could also facilitate food trade with Iran (GCR, 2020).

Railway and road infrastructure between Russia and Iran is not well developed and the contribution of non-marine transport of agricultural commodities is currently low. On the Iranian side, the constant intervention of the government in the domestic agricultural market is another issue that impedes the long term provision of fruit and vegetable exports to the Russian market, as the Iranian Market Control Centre frequently implements restrictions on the export of agricultural and food commodities once domestic food shortages occur (Kuzehgarkaleji, 2020a).

Despite the deficiencies in transport infrastructure, the bilateral food trade has increased in recent years and can be expected to further develop in the future (Figure 9). After years of negotiations, on October 27, 2019, a free trade agreement between the Eurasian Economic Union (EAEU) and Iran took effect (EAEU, 2020). This represents a key decision to expand Iran's trade relationships with former members of the Soviet Union, and Russia in particular. The main objective of the agreement is the liberalisation and facilitation of the trade between the parties through, inter alia, reduction or elimination of tariff and non-tariff barriers (EAEU-Iran, 2019). This interim preferential trade agreement (PTA) was declared to lead to a free trade agreement within three years (EAEU-Iran, 2019, Article 1.3, §3). At its primary stage, the EAEU-Iran interim PTA covers approximately 55% of the total trade between the partners and focuses on selected agricultural and industrial products. Iran grants preferential treatment for meat and other food commodities, as well as metals, electronics and other items. The average import tariff applied by Iran to imports from the EAEU is reduced from 22.4% to 15.4% for manufactured commodities and from 32.2% to 13.2% for agricultural commodities. 360 commodity categories are covered in the agreement. Furthermore, Iran receives preferential treatment for exports of fruit and vegetables and other selected products. The average import tariff applied by the EAEU on Iran is reduced for agricultural commodities from 9.6% to 4.6% and for industrial commodities from 8% to 4.7%, with 502 commodity categories being covered (Adarov and Ghodsi, 2020). However, the available data on tariff changes shows that barley and corn are not included at this stage. A first study investigating the effects of this EAEU-Iran free trade agreement employing a gravity model framework projected a greater increase of exports by EAEU members to Iran than by Iran to the EAEU members (Adarov and Ghodsi, 2020).

2.5 CONCLUSIONS

In this chapter, we examined Russia's food trade with four key destination markets in the MENA region. Food trade is the most important component of the bilateral economic relationships with Saudi Arabia, Iran and Egypt, which are energy net-exporters like Russia (Table 1). Regarding Turkey, the sole energy net-importer among the considered cases, the food trade only accounts for 13% of the total trade, which is dominated by Russian energy exports. In all three cases, Russian food exports clearly outweigh imports. Due to unfavourable climatic conditions, the majority of MENA countries are unable to produce sufficient grain to meet the consumption of growing populations. Russia thus emerged as a main supplier of wheat, as well as barley and maize to the neighbouring region. After Saudi Arabia approved the import of Russian wheat in August 2019, only few MENA countries continue to disallow the import of Russian wheat, most notably Algeria, the world's third largest wheat importer, as well as Iraq.[17] However, regardless of Algeria approving wheat imports from Russia, its overall grain exports to the MENA region are unlikely to increase much further in the future, as the region already sources most of

17 Iraq, however, imports large quantities of wheat flour from Turkey, which imports wheat from Russia. Thus, Iraq virtually already imports Russian wheat via Turkey in an indirect way.

its grain from Russia or competing Black Sea exporters, such as Ukraine, Kazakhstan or Romania.

As a consequence, a goal outlined by Russian officials is the diversification of Russia's food exports, and thus the development of new destination markets for food export products other than grains and vegetable oils. In this respect, Russia recently started to export notable amounts of chocolate products and poultry meat to Saudi Arabia, which had previously almost exclusively imported barley from Russia. This diversification in Russia's exports to the high-income gulf country follows an improvement in the bilateral relations due to a fruitful cooperation in the energy market since 2016 and corresponds to Russia's proclaimed effort to quadruple food exports to Saudi Arabia by 2024. Regarding Egypt and Turkey, the total food trade does not exhibit a clear upwards or downwards trend over the past decade.

The considered food trade relationships are strongly shaped by political disputes or the improvement of diplomatic ties. Russia appears to use import restrictions on specific food products to support domestic production in order to substitute imports and to reach self-sufficiency, or even gain the capacity to export – an approach that several studies focusing on Russia's import restrictions versus Western countries in 2014 have previously analysed (Liefert and Liefert, 2015, Wegren, 2014, Banse et al., 2019). The trade dispute surrounding the import of Turkish tomatoes illustrates how Russian import quotas are maintained to (successfully) encourage domestic greenhouse tomato production. Generally, food exports are often restricted using non-tariff measures, as products are rejected over concerns about food safety, product quality or the alleged non-compliance with prevailing phytosanitary standards. While it must be expected that non-compliant food cargos be rejected from government agencies that control the quality of food imports, the sequence of cargo rejections in the considered cases suggests that the product quality tests are partly influenced by political considerations or previous adjustments in trade policies or quality standards by the other side.

By exporting wheat and other grains to the import-dependent MENA region, Russia has achieved building meaningful economic trade relationships to countries that are also primarily energy exporters and thus competitors. After reaching low points in 2016 due to inter alia Russia's involvement in the Syrian civil war, a stand-off in international energy markets and various disputes over product quality, the food trade relationships with the selected MENA countries have largely improved recently. While the food trade was repeatedly disrupted by political interventions in recent years, its central component, the grain trade, can be expected to remain stable in the long-run due to its unequivocal mutual benefit: Because of climatic and geographic advantages, Russia can competitively produce and ship grain to MENA countries, which lack sufficient production capacity to meet domestic consumption.

3 PRICE FORMATION WITHIN EGYPT'S TENDER MARKET: IMPLICATIONS FOR BLACK SEA EXPORTERS[18]

18 A largely congruent version of this chapter was published in the peer-reviewed journal Agricultural Economics (see Heigermoser et al., 2021b).

Over the past two decades, expanding grain production in the Black Sea region has resulted in growing wheat exports, particularly to the Middle East and North Africa (MENA) region. Egypt, the world's largest wheat importer, became a key destination market for Black Sea exporters such as Ukraine, Romania, and especially Russia, the world's largest wheat exporter since 2017/18. Half of Egypt's wheat imports are managed by the General Authority for Supply Commodities (GASC), a state procurement agency for food commodities. The GASC regularly issues tenders to purchase considerable quantities of wheat on international markets, which are closely watched by the global grain industry. In particular, Thompson Reuters and numerous other business news and consulting agencies routinely provide detailed information on trading companies participating in the tenders, the price offers submitted, as well as the volumes and origins of the wheat offers accepted by the GASC.

The interest in GASC tenders coincides with Russia moving to become the largest wheat exporter in the world. As futures markets for Black Sea wheat, which could facilitate price discovery are still underdeveloped, reliable information on actual prices in this rather opaque market is scarce. In this situation, GASC wheat tenders provide up-to-date information on price levels in the Black Sea wheat market and foster competition between trading companies engaging in the tender calls, which drives the submitted price offers towards competitive levels. GASC tenders regularly reveal the trading companies that are able to deliver wheat to Egyptian ports close to the Suez channel at the lowest cost, which usually implies competitiveness also beyond this vital chokepoint of global grain trade.

Given the informational value of GASC tender prices and Egypt's key geographical position within global wheat markets, this study addresses the following research questions: To what degree is the GASC tender market integrated with major export markets and what is the extent, i.e. the geographic boundaries, of this market? What are the characteristics of price formation processes in the GASC tender market? In particular, which price relationships and price leadership can be determined? These research questions are particularly relevant since the Black Sea region has advanced to be the global center of physical wheat exports, with

Russia and Ukraine jointly accounting for 29% of global wheat exports in 2019/20 (USDA, 2021a). This significance is expected to increase even further, as Russia in particular bears large additional grain production and export potential (Schierhorn et al, 2014, Svanidze and Götz, 2019). On the other hand, the GASC is one of the largest importing institutions within the international wheat market, implying a high concentration of wheat import demand in the Black Sea market.

To shed light on the presented research questions, we study the relationship between the GASC tender price and export prices of the top eight global wheat exporters employing the Johansen (1988) multivariate cointegration framework. We determine the extent of the GASC tender market and its integration with the Black Sea and further major wheat export markets, particularly the USA and France. Furthermore, price interdependencies and (weak) exogeneity of particular market locations are investigated. We construct a continuous series of GASC tender prices based on a unique database of transaction-specific records on prices, quantities, countries of origin and companies supplying wheat to the GASC within the tender system between July 2005 and June 2019. This study is unique in investigating how prices in grain export markets relate to prices negotiated within a state tender system, which is common among grain-importing countries in the MENA region.

This research contributes to the still limited number of analyses investigating the integration of grain markets in the Black Sea region. Existing studies to-date typically follow a bivariate cointegration approach. Götz et al. (2013a, 2016a), and Djuric et al. (2015) find that Russian, Ukrainian and Serbian wheat markets are strongly integrated with the international wheat market, while taking into account the disintegrating effects of export restrictions. Goychuk and Meyers (2014) determine that French and US export prices adjust to Russian export prices within the time period of 2004 through 2010. Arnade and Hoffmann (2019) establish that the Black Sea region plays an important role for the international maize markets price discovery, especially in periods of high exports. Araujo-Enciso and Fellmann (2020) show that the harvest failures in the Black Sea region can have severe effects on food security in the import-dependent

MENA region. Svanidze et al. (2019) find that wheat import prices of South-Caucassian and Central Asian countries adjust to Black Sea export prices. This is in line with further research generally suggesting that export prices lead import prices when grain markets are considered (Rosa et al., 2014, Hassanzoy et al., 2016). Export prices are, however, found to adjust to import prices in the international rice market (Jamora and von Cramon-Taubadel, 2015). To the best of our knowledge, this is the first study that investigates Black Sea wheat markets following a multivariate cointegration approach.

Some existing studies employ multivariate cointegration models to analyze the integration and interdependencies in global wheat markets. Ghoshray (2006) finds US wheat export prices to lead export price developments in the international market, accounting for quality differences between wheat classes. By contrast, Mohanty et al. (1999), not explicitly distinguishing between different quality classes, conclude that one single export price leading the global wheat market does not exist. Arnade and Vocke (2015) investigate seasonal variations in wheat price leadership and find that Southern Hemisphere exporters dominate price discovery in the first half of the year, while US prices lead in the second half, after the Northern Hemisphere harvest. In an earlier study, Goodwin (1992) argues that transportation costs between market locations cannot be disregarded if the Law of One Price (LOP) in international wheat markets is investigated. In this study, we evaluate the role of transportation costs based on freight cost data recorded in the GASC tender data-base and transportation costs implied in the multivariate $VECM$. Employing the Johansen cointegration framework, further multi-locational agricultural commodity markets are investigated in Asche et al. (2012), Pierre and Kaminski (2019), Ihle et al. (2012), and González-Rivera and Helfand (2001).

This chapter is organized as follows: In the next section, we provide background information on the GASC wheat tender market, while the methodological framework is presented in section 3.2. In section 3.3, the data-base used in the analysis is described and estimation results are discussed in section 3.4. Finally, we provide concluding remarks.

3.1 EGYPT'S WHEAT TENDER MARKET

Egypt's state procurement agency for food commodities (GASC) manages around half of the country's wheat imports, while the other half is handled by private trading companies (Ghonheim, 2015). Over the past five seasons, the GASC imported around 5.5 million tons of wheat per season via its tender system. Wheat tenders are typically held every ten to twelve days between June and February, but rarely issued in March through May, when the agency procures domestically produced wheat (McKee, 2013). Announcing a tender, the GASC asks authorized trading companies to submit one or several sealed price offers to supply wheat cargos of 55,000 to 60,000 t. The offers must contain a 'free on board' (FOB) price and a separate freight offer, both denoted in USD per ton (Heigermoser, 2017). The delivery to an Egyptian port is typically scheduled four to six weeks after the tender date. The companies may source wheat solely from origins approved by the GASC based on its quality standards. On average, the agency buys three to four cargos per tender.

Similar organizations and tender systems exist in the majority of countries in the MENA region. The most notable further agencies are the Algerian Office Algérien Interprofessionnel des Céréals (OAIC) and the Saudi Arabian Saudi Grains Organisation (SAGO, see Table A1 in the appendix for details). However, the GASC stands out versus other such agencies in four respects: tenders are issued at a relatively high and regular frequency; large and standardized amounts of wheat are purchased; transparency on tender results is rather high; and the top three wheat exporters, namely Russia, France and the USA, are all approved to participate in the tenders.

Figure 10 displays the countries of origin of GASC wheat imports between 2005/06 and 2018/19. The share of the Black Sea exporters Russia, Romania and Ukraine constantly increases over this period, ultimately reaching 94%, 99% and 85% in 2016/17 through 2018/19. In 2010/11, Russia completely bans all wheat exports after severe harvest shortfalls, resulting in higher imports from France and the USA. Over the whole displayed period, 43% of GASC wheat imports originate from Russia, followed by

France (16%) and the USA (15%). However, after 2011/12 the GASC purchases only minor quantities from France. An exception is the 2014/15 season, when French wheat accounted for 35% due to a record crop in the country. The USA had been the largest supplier to the GASC prior to the 2006/07 season. However, after 2010/11 it sells wheat to the GASC only occasionally. By contrast, both Romania and Ukraine gain market shares from 2011/12 onwards after the GASC had approved the two countries as additional suppliers in an effort to 'boost competition amongst Black Sea origin wheat' (Reuters, 2011). Romania and Ukraine successfully compete with Russia in the 2012/13 season through to 2015/16. However, from 2016/17 through to 2018/19, Russian wheat clearly dominates GASC imports, reaching shares of 65%, 81% and 59%, respectively.

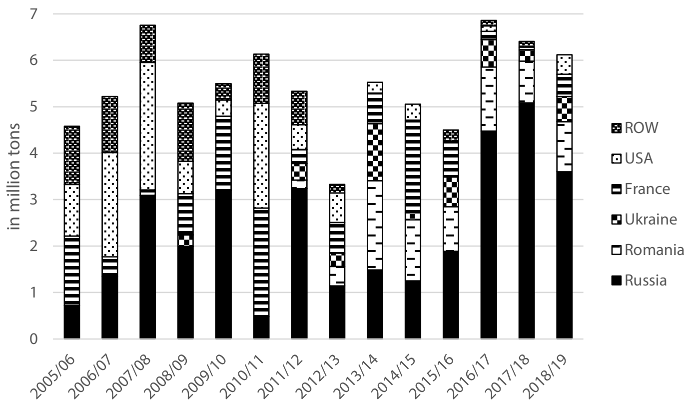

Figure 10: Countries of origin of GASC wheat imports

Note: Seasonal imports are aggregated based on the tender date, not the delivery date. ROW denotes 'Rest of World' and aggregates imports from Argentina, Australia, Canada, Germany, Kazakhstan and Poland.

Source: Own illustration based on Zerno Online (2020).

While Black Sea exporters are the most important suppliers of wheat to the GASC, Egypt is conversely the top destination market for wheat from Russia, Romania and Ukraine. Over the past decade, the share of wheat exported to Egypt amounted to 25%, 20% and 15% of their total wheat exports, respectively (see also Figure A4 in the appendix). The share of wheat exports by France to Egypt decreased from 7% (2009 to 2013) to 4% (2014 to 2018) and by the USA from 5% to 1% of their total wheat exports, respectively (UN Comtrade, 2020).

In the time period underlying this study, the GASC closed transaction deals with 15 to 22 trading companies per season, while numerous additional companies submitted price offers that were not accepted by the agency. The top five companies supplying wheat to the GASC were the Louis Dreyfus Company (with a share of 10.9% in GASC's wheat imports), Glencore (7.6%), Ameropa (6.9%), GTCS (6.9%) and Cargill (6.5%). The degree of concentration in the GASC tender market is characterized by the concentration ratio and the Herfindahl-Hirschmann index (HHI, Rhoades, 1993) for each season (see A2 in the appendix). Results suggest low concentration among sellers participating in GASC tenders. We interpret this as further evidence for strong competition among wheat suppliers in the GASC tender market, ensuring competitive price offers.

3.2 METHODOLOGY: MULTIVARIATE COINTEGRATION AND THE VECM

Spatial market integration analysis typically investigates the relationship between prices for one homogenous commodity at n different locations. If a homogenous commodity is physically traded between n locations within one market, and prices in these locations follow a common trend, i.e. share the same long-run information (González-Rivera and Helfand, 2001), a spatially integrated market exists. The physical flow of goods from surplus location i to deficit location j is triggered if the price difference between i and j exceeds the costs of transporting the good between the locations. This process of spatial arbitrage causes the co-movement of prices at the different locations and ensures that deviations from the common long-run equilibrium only occur in the short-run until corrected. The Law of One Price (LOP) describes this spatial price relationship.

Considering the bivariate case of $n = 2$, the LOP in its weak (strong) form states that the difference between prices at locations i and j does not exceed (is equal to) the costs of transporting the commodity between the locations (Fackler and Goodwin, 2001). In a multivariate framework with $n > 2$, two market locations can also be integrated indirectly if trade flows to or from other market locations occur.

Bivariate models are frequently estimated to analyze the spatial market integration of various price pairs. This approach is justified if one of the n $(n > 2)$ locations is a central market exogenous to all other market locations, while independent price interlinkages between non-central locations do not exist. However, as the number of considered locations increases, market prices are likely determined simultaneously at various locations (i.e. price series are endogenous in the system). To account for interdependence structures that are more complex, the relationships between n locations are investigated within a multivariate cointegration framework (Johansen, 1988). Herein, an integrated market with n locations shows exactly $n - 1$ cointegration vectors, which implies pairwise cointegration of prices at any two market locations (Johansen and Juselius, 1994). In a bivariate approach, $(n^2 - n)/2$ price pairs could be considered that can, however, only be normalized differently to represent a maximum of $n - 1$ cointegration relationships. The caveat of a bivariate approach is that the $n - 1$ long-run price transmission elasticities can vary in size depending on the choice of the considered price pairs, which is theoretically implausible (Asche et al., 2012). Within a multivariate approach, this problem is avoided.

Following Johansen (1988), a multivariate cointegrated system can be represented as a *VECM*. The basic intiuition of a *VECM* is that present price changes are a function of lagged deviations from long-run equilibria shared by cointegrated prices, lagged price changes, as well as a constant. Formally, a *VECM* is represented by

$$\Delta p_t = \mu + \Pi p_{t-1} + \sum_{i=1}^{k} \Gamma_i p_{t-1} + e_t \tag{1}$$

where $\boldsymbol{p_t}$ corresponds with a n-dimensional vector of prices in natural logarithm for a good traded at n different locations, while $\Delta \boldsymbol{p_t}$ denotes the price changes from period $t-1$ to period t and μ represents a vector of constant terms. The $n \times n$ matrix $\boldsymbol{\Pi}$ has reduced rank $r = n - s$, with $s = 1$ if all n prices share exactly one common trend. The matrix $\boldsymbol{\Pi}$ can be rewritten as $\boldsymbol{\Pi = \alpha\beta'}$, where $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ are both $n \times r$ matrices. The matrix $\boldsymbol{\beta}$ contains the (normalized) cointegrating vectors characterizing long-run equilibria for r linear combinations of prices. To include a constant in the cointegration relationships, the matrix characterizing the long-run equilibrium relationship has been modified to $\boldsymbol{\Pi p_{t-1} = \alpha(\beta_1' p_{t-1} + \beta_0)}$, where the $\boldsymbol{\beta_1}$ matrix includes the coefficients measuring the magnitude of the cointegration relationships and the $\boldsymbol{\beta_0}$ vector contains the constant terms.[19] The loading matrix $\boldsymbol{\alpha}$ contains the speed of adjustment coefficients denoting the speed at which $\Delta \boldsymbol{p_t}$ moves to correct r past short-run disequilibria. To ensure that the n-dimensional error term $\boldsymbol{e_t}$ is serially uncorrelated, k lagged price changes are included in the model. The $n \times n$ matrix $\boldsymbol{\Gamma_i}$ thus denotes the reaction of $\Delta \boldsymbol{p_t}$ to price changes lagged by i periods, with $i = 1, 2, \ldots, k$.

Referring to the definition of market integration proposed by González-Rivera and Helfand (2001), we expect the rank of matrix $\boldsymbol{\Pi}$ to be $r = n - 1$, which implies r cointegrating vectors and one common stochastic trend. If this condition holds, the cointegrating vectors can be normalized to represent pairwise cointegration between any two analyzed price series (Johansen and Juselius, 1994). After normalization, the coefficients of the j^{th} column of the $\boldsymbol{\beta}$ matrix, $j = 1, \ldots, r$, correspond to the long-run price transmission elasticity, a measure of the degree of long-run price transmission, in the j^{th} cointegration relationship. The closer the coefficients are to unity, the stronger is the market integration between the respective locations and the more likely the LOP is to hold. The

19 To give better intuition, consider the bivariate (i.e. $n = 2$) case with $r = 1$ cointegration relationship. Δp_t^1 then depends on the deviations from the long-run price equilibrium it shares with p_t^2. The long-run equilibrium can be represented as $p_t^1 = \beta_0 + \beta_1 p_t^2 + \varepsilon_t$. In the bivariate case, ε_{t-1} denotes the disequilibrium, or the error correction term. In a multivariate VECM, Δp_t can be a function of various (i.e. $r > 1$) lagged disequilibria.

elements in the j^{th} row of the loading matrix α represent the short-run characteristics of price transmission. Each of the n prices within the multivariate framework adjusts to each of the r past disequilibria (error correction terms) within the system. The closer the adjustment parameters are to unity in absolute value, the faster the speed at which the respective price adjusts to correct a deviation from a long-run equilibrium. In a cointegrated system, a large adjustment parameter thus indicates that the respective price is strongly adjusting to changes of another price and is thus following it. By contrast, low (close to zero) adjustment rates of a price indicate only slight adjustment to changes of other prices, which suggests that the respective price is leading the price developments in the system.

The extent of the GASC wheat tender market is specified based on the largest set of prices (including the GASC tender price) for which the condition of common long-run information (i.e. a $\boldsymbol{\Pi}$ matrix of rank $r = n - 1$) holds, following a sequential specific-to-general approach (Rashid, 2004, Gonzalez-Rivera and Helfand, 2001, Jha et al., 2008, Sekhar, 2012). We start the cointegration analysis considering the GASC tender price and one export price exclusively ($n = 2$) . If $n - 1$ cointegrating vectors are identified within this system, further export prices are successively added until the inclusion of an additional price series results in $r < n - 1$ or $r = n$ cointegrating vectors. The order in which export prices are added to the multivariate framework corresponds to the size of the export country's share in the GASC tender market, i.e. countries with the largest share are considered first.

3.3 DATA CHARACTERISTICS AND PROPERTIES

The analysis is conducted for a data-base consisting of nine monthly wheat price series, namely the GASC 'cost and freight' (CFR) wheat tender price and eight FOB wheat export price series of the world's largest wheat exporting countries (see Table 2, and Table A3 in the appendix for descriptive statistics). The data set lasts from July 2011 – after the Russian grain export ban, when no wheat export prices were recorded – through to June 2019. Within our investigation period, the GASC issued 201 tenders and purchased 694 wheat cargos.

The monthly GASC wheat tender price series is constructed based on a comprehensive data-base comprising information on each individual wheat tender transaction (see Figure 11). We select the highest CFR price accepted by the GASC within all wheat tenders issued in one month as the respective GASC wheat tender price, which is motivated by the following theoretical considerations: Exporters from different countries provide price-quantity offers to the GASC within an open wheat tender, theoretically representing the wheat supply curve of the GASC wheat tender market. The GASC wheat tender equilibrium price p_t^{eq} is given by $ask_t^{acpt} \leq p^{eq} < ask_t^{rjct}$, with ask_t^{acpt}, the highest offer price accepted, and ask_t^{rjct}, the lowest offer price rejected by the GASC. Since rejected price offers (ask_t^{rjct}) are not recorded in the tender transaction data-base, the highest accepted offer price (ask_t^{acpt}) represents the best approximation of the specific market equilibrium price.[20]

The resulting tender price series contains 16 missing values (16.7% of the observations of the price series), corresponding to the periods when no wheat tenders were issued. As missing values are also observed in consecutive months, linear interpolation is not feasible here. We therefore employ a linear imputation technique (similar to Goodwin, 1992, and Svanidze et al., 2019) and simulate the missing values building on French export prices, which are highly correlated with the GASC tender prices.[21]

20 For comparison, we have also constructed a series of average tender prices, as well as a series based on the lowest CFR price within one month. While the model results do not change qualitatively, the estimated price transmission elasticities and speed of adjustment parameters are smaller in size. We interpret this as evidence for the highest CFR price containing the largest informational value on the export markets under consideration.

21 As a robustness check, all subsequent estimations were also conducted using a linearly interpolated series of GASC tender prices. The results do not change fundamentally, and the overall conclusions of the paper remain unaffected. Additionally, we estimated the VECM with interaction dummy variables to filter out the effect of the missing observations (Table A6). Also here, the results do not change significantly and the overall conclusions remain unaffected.

Table 2: Database utilized in the spatial market analysis

Group	Country	Price type	Data Source
GASC	**Egypt**, tender prices	Highest accepted CFR offer, monthly, USD/t	Zerno Online (2020)
Black Sea exporters	**Kazakhstan**, milling, Aktau port	FOB, monthly, USD/t	FAO (2019)
	Russia, milling, deep-sea ports	FOB, monthly, USD/t	FAO (2019)
	Ukraine, milling	FOB, monthly, USD/t	FAO (2019)
Non-Black Sea exporters	**Argentina**, Trigo Pan, up river	FOB, monthly, USD/t	FAO (2019)
	Australia, ASW, Eastern states	FOB, monthly, USD/t	FAO (2019)
	Canada, CRWS, St Lawrence	FOB, monthly, USD/t	FAO (2019)
	France, grade one, Rouen port	FOB, monthly, USD/t	FAO (2019)
	USA, no. 2 SRW, Gulf ports	FOB, monthly, USD/t	FAO (2019)

Note: The sample period ranges from July 2011 to June 2019. CFR and FOB denote 'cost and freight' and 'free on board' and refer to prices at importing and exporting port facilities, respectively (see ICC, 2019).

Source: Own illustration

The analysis covers monthly FOB wheat prices of Russia, USA, Canada, France, Ukraine, Argentina, Australia and Kazakhstan, which jointly account for 90% of global wheat exports (USDA, 2021a). Comparing the exporters' shares in global wheat exports and the Egyptian tender market, Table A4 in the appendix shows that the US share in the Egyptian wheat tender market has recently decreased to 2.2%. As discussed in section 3.1, Romania also exports considerable quantities of wheat to Egypt. However, since data on Romanian wheat prices could not be accessed for the time period underlying our analysis, Romania is not covered in this study. Russia typically exports soft winter wheat of class four with a protein content of between 12% and 13%, while France also exclusively exports soft wheat. To ensure comparability, we select soft red winter (SRW) wheat to represent wheat exported by the USA, although hard red winter (HRW) wheat is the class primarily exported from the USA. SRW wheat has a lower protein content compared to HRW wheat and is the class preferred by the GASC.[22]

22 The GASC frequently adjusts the minimum protein levels it requests from suppliers. In February 2018, the levels were adjusted to 11.5% for wheat from Russia, Romania and Ukraine and 11% for French and US-SRW wheat, respectively (Reuters, 2018b).

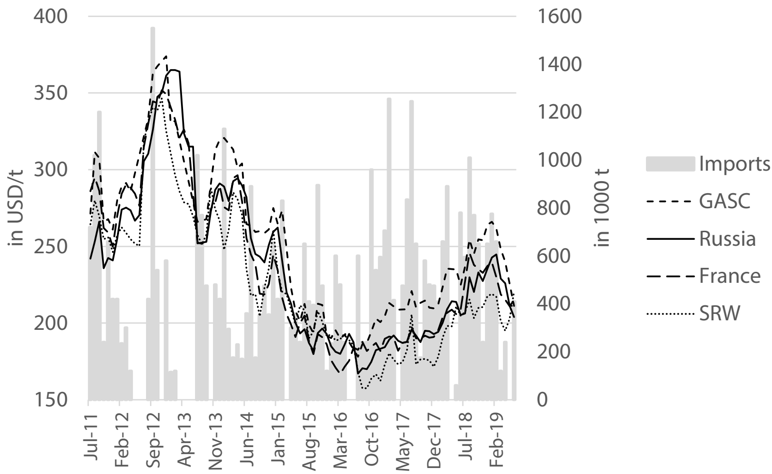

Figure 11: GASC imports, CFR tender prices and selected FOB export prices

Source: Own illustration based on FAO (2019) and Zerno Online (2020)

Prior to our cointegration analysis, the time series properties of the nine wheat price series are examined. The order of integration of each series is determined employing Augmented Dickey-Fuller (ADF) unit root (Dickey and Fuller, 1979) and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) stationarity tests (Kwiatkowski et al., 1992). The lag length in the ADF and KPSS test is determined by the Schwarz Information Criterion and the Newey-West bandwidth method, respectively. Both tests suggest that all price series are non-stationary mostly at the 1%, and at least at the 5% level of significance. The Kazakh price series is an exception with a rejection of stationarity only at the 10% significance level (see Table A5 in the appendix). The non-stationarity of the data motivates us to investigate the price relationships within a cointegration framework.

3.4 ESTIMATION RESULTS

3.4.1 Integration and extent of the GASC wheat tender market

The extent of the GASC tender market is determined by sequential trace tests for multivariate cointegration, following the specific-to-general approach outlined in section 3.2.[23] Results suggest that Russia, the biggest supplier of wheat to the GASC, clearly belongs to the tender market (Table 3). The wheat markets of France and the USA are included in the multivariate system since the respective null hypotheses of $n \leq 2$ and $n \leq 3$ cointegration vectors is rejected at the 10% significance level. We explain the weaker evidence for cointegration of France and the USA by the lower frequency of their wheat exports to Egypt. The test results for Ukraine, Argentina, Kazakhstan, Canada and Australia indicate that their inclusion would result in $r < n - 1$ cointegration vectors. This implies that the respective price series do not belong to the same economic market. Therefore, Ukraine, Argentina, Kazakhstan, Canada and Australia are not included in the multivariate system. We explain the exclusion of Ukraine from the GASC tender market by its geographical proximity to Russia's wheat export market, leading to a high correlation of 0.996 between Russian and Ukrainian wheat export prices. Thus, the two price series likely share an additional, independent common trend implying $r < n - 1$.[24] The exclusion of Argentina, Kazakhstan, Canada and Australia from the GASC tender market is in line with their rather low share in GASC wheat

23 As a robustness check, we also conducted sequential trace tests following a general-to-specific approach, consecutively excluding price series on the basis of resulting increases in the model log likelihood. This approach also determines that the system containing GASC, Russian, French and US prices represents the largest set of prices containing $n - 1$ cointegrating relationships.

24 We also conducted subsequent VECM estimations replacing Russian with Ukrainian export prices. The results were qualitatively similar. This finding suggests that subsequent findings regarding to Russian prices can be generalized to further Black Sea exporters such as Ukraine and Romania, which grow wheat of a similar quality.

tenders. Further, Canada and Kazakhstan predominantly export higher protein wheat, while the exclusion of the Southern Hemisphere exporters Argentina and Australia likely results from greater geographical distance, as well as seasonal factors (Arnade and Vocke, 2015). We conclude that there exist three cointegrating vectors in the system that includes the GASC, Russia, France and the USA. Prices in these four locations are cointegrated in all possible pairings and share one common stochastic trend.[25]

Table 3: Johansen (1988) likelihood ratio test for the number of cointegrating vectors

Market locations (n) included	Rank (r) of matrix Π	Trace statistic
GASC; Russia	0 1	27.12*** 2.66
GASC; Russia; France	1 2	16.95* 3.29
GASC; Russia; France; USA	2 3	16.24* 3.20
GASC; Russia; France; USA; Ukraine	3 4	15.11 2.56
GASC; Russia; France; USA; Argentina	3 4	12.67 4.01
GASC; Russia; France; USA; Kazakhstan	3 4	15.02 3.98
GASC; Russia; France; USA; Canada	3 4	10.55 3.75
GASC; Russia; France; USA; Australia	3 4	11.20 3.32

Note: Null hypothesis for trace test is $r = h$ against the alternative of $r > h$, with h specified in the second column. Sample period lasts from July 2011 to June 2019 (96 observations). The lag length in the VAR models is set to three to ensure that error terms are serially uncorrelated. Critical values are from Osterwald-Lenum (1992). ***, **, * denote rejection of null hypothesis at 1%, 5% and 10% level of significance, respectively.

Source: Own estimations

25 Applying more recently developed wavelet methodologies to daily price data, Nigatu and Adjemian (2020) show that wavelets are equipped to portray more complex time-varying price interdependence patterns that linear cointegration tests might disregard. However, as the conducted Johansen tests suggest linear cointegration in our case, we leave the question of non-linearity of price relationships to future research.

The $n-1$ normalized parameter estimates of the cointegration relationships are presented in Table 4. The β_1^i coefficients characterizing the long-run price transmission elasticities between the GASC tender price and the export prices of Russia, France and the USA equal 0.88, 0.89 and 0.91, respectively. Following Asche et al. (2012), the LOP is tested uwsing a multivariate likelihood ratio (LR) test distributed as $\chi^2(3)$ by jointly restricting $\beta_1^1 = \beta_1^2 = \beta_1^3 = 1$. The test statistic of 5.80 (p-value: 0.122) does not allow for rejection of the null hypothesis of complete price transmission within the whole multivariate system in the long-run. This provides evidence for a highly integrated market. However, LR tests on the LOP holding for single market locations individually (i.e. $\beta_1^i = 1$), suggests that the respective null hypothesis for the GASC-Russia and GASC-France price pairs can be rejected at the 5% significance level.

The GASC tender price is a CFR import price equal to the sum of the FOB price observed in an exporting location and the costs of transporting wheat to Egypt. Thus, if β_1^i is restricted to 1 for $i = 1, 2, 3$, the constant term β_0^i is expected to reflect the respective transportation costs. As all prices are denoted in natural logarithm, the transportation costs implied in β_0^i are a constant proportion of the FOB price.[26] We compare the average transportation costs implied by the constant terms (tc_t^i) with the observed average freight rates recorded in the GASC tender data set ($\overline{tc}^i$), which amounted to 13.5, 15.5 and 29 USD/t for the transport of wheat from Russia, France and the USA to Egypt, respectively. The implied transportation costs (given by $\beta_0^i * \bar{p}^i$, with $\bar{p}^i$ equal to the mean of prices observed at location i as given in Table A3) are equal to 16.65, 18.95 and 27.25 USD/t, for Russia, France and the USA, respectively. The χ^2 test does not allow rejecting the null hypotheses on statistical equality of the implied and observed transportation costs for Russia, France and the USA, respectively. We interpret this as evidence for high substitutability

26 Besides arbitrage costs, substitution costs that result from quality differences between goods traded within one market will also be reflected in the constant terms (see Asche et al., 1999).

and thus small quality differences between the wheat classes included in the model.[27]

Table 4: Market integration and transportation costs in the GASC tender market

Price pair containing GASC and exporter i:	Russia	France	USA
Long-run price equilibrium			
Price transmission elasticities (β_1^i)	0.883 [0.040]	0.885 [0.045]	0.914 [0.076]
Constant term for unrestricted β_1^i (β_0^i)	0.706 [0.220]	0.696 [0.247]	0.577 [0.410]
Law of One Price (LOP)			
Joint LOP test ($\beta_1^1 = \beta_1^2 = \beta_1^3 = 1$)	(0.122)		
Individual LOP test ($\beta_1^i = 1$)	(0.022)	(0.044)	(0.313)
Constant term for β_1^i restricted to 1 ($\beta_0^{i,restr}$)	0.069 [0.011]	0.075 [0.013]	0.116 [0.017]
Implied vs. observed freight costs			
Average observed export price ($\bar{p}^i$)	237.9 USD/t	236.9 USD/t	227.1 USD/t
Average observed freight cost ($tc^{i,obs}$)	13.5 USD/t	15.5 USD/t	29 USD/t
Implied transaction costs ($tc_t^i = \beta_0^{i,restr} \times \bar{p}^i$)	16.5 USD/t	17.8 USD/t	26.3 USD/t
LR test on equality of implied and observed freight costs ($\beta_0^{i,restr} = \frac{t\bar{c}^{i,obs}}{\bar{p}^i}$)	(0.133)	(0.168)	(0.173)

Note: Cointegrating vectors are normalized to represent pairwise cointegration with GASC tender prices. Standard errors are in []. P-values are in (). Multivariate likelihood ratio test of the LOP distributed as $\chi^2(3)$.

Source: Own estimations

27 We additionally estimate a VECM including HRW prices instead of SRW for the USA. While the price transmission elasticity parameter remains unaffected, the respective intercept term turns negative when the elasticity is restricted to unity. This suggests that the FOB price for higher-quality HRW wheat is on average higher than the GASC import price, which comprises an FOB price for lower-quality soft wheat plus freight costs. This result illustrates the quality segmentation of the international wheat market and affirms that SRW wheat is the appropriate quality class in the given context.

3.4.2 Interdependencies and price leadership

We estimate a multivariate $VECM$ to assess the interdependencies between the GASC tender price and the export prices of Russia, France and the USA (Table 5). Each $VECM$ equation contains the error correction terms of the three cointegration relationships, as well as three lags for each endogenous price series on the right-hand side of the equation. The number of lags was selected based on the Akaike Information Criterion (AIC). Portmanteau autocorrelation and White heteroscedasticity tests indicate that the model residuals are free from autocorrelation and heteroscedasticity.

The estimated speed of adjustment coefficients suggest strong interdependencies between the GASC tender price and export prices of Russia and France, while the US export price adjusts to price changes in the other market locations at a lower speed. The Russian wheat price corrects disequilibria with the GASC tender price at the highest speed observed in the $VECM$ (-0.7). The GASC tender price adjusts to deviations from its equilibrium with French (Russian) export prices, correcting 53% (31%) of a deviation within one month. The slow adjustment of the US wheat export price to the price changes in the other market locations is statistically significant only for the equilibrium shared with the GASC tender price (-0.22).

Moreover, our results show that particular export prices adjust to error correction terms from multiple cointegration relationships. These additional, 'off-diagonal' adjustments represent a unique extension of multivariate over bivariate $VECM$ and denote one exporter's price adjustment to deviations from a long-run price equilibrium shared by the GASC tender price and the export price of a competing origin. Russian prices show statistically significant adjustment of 37% to disequilibria in the France-GASC cointegration relationship, similar to the French export price adjusting to the Russia-GASC cointegration relationship by almost the same degree (-0.36). These results suggest strong competition between the two largest wheat suppliers in the GASC tender market, namely France and Russia.

Testing for weak exogeneity corresponds to jointly restricting the three adjustment parameters of each column of Table 5 to zero. Results indicate that weak exogeneity of Russian and GASC prices can be rejected at the 1% significance level, suggesting that Russian and GASC prices adjust to price developments in the whole market. However, regarding France and the USA, we cannot reject weak exogeneity at the same level of confidence. The test provides some evidence that French and – at a lower level of confidence – US prices are weakly exogenous to the cointegration system.[28] We interpret this finding as indication that price offers by Black Sea wheat sellers to the GASC are intentionally set at a level closely related to the competing French wheat export price. This explanation implies that the Russian wheat market is not perfectly competitive, which was also suggested in Pall et al. (2013).

Table 5: Adjustment parameter estimates from multivariate VECM

Deviations from long-run equilibrium of price pair	Russia	France	USA	GASC
Russia-GASC	-0.70*** [0.13]	-0.36** [0.15]	-0.31 [0.20]	-0.31** [0.15]
France-GASC	0.37** [0.13]	0.10 [0.14]	0.29 [0.19]	0.53*** [0.14]
USA-GASC	0.10 [0.08]	0.09 [0.09]	-0.22* [0.12]	0.00 [0.09]
Weak exogeneity tests	26.36*** (0.00)	6.23 (0.10)	7.31* (0.06)	14.42*** (0.00)
Adjusted R^2	0.44	0.17	0.14	0.14
Autocorrelation test	135.97 (0.75)			
Heteroscedasticity test	322.25 (0.18)			

Note: Three lags are included in the VECM. Lag-adjusted sample runs from November 2011 to June 2019. ***, ** and * denotes statistical significance at the 1%, 5% and 10% level. Standard errors in []. P-values in ().Test statistics of LR tests for weak exogeneity distributed as χ^2 (3). Portmanteau test statistic for no autocorrelation up to lag 12 distributed as χ^2 (148). Joint White heteroscedasticity test distributed as χ^2 (300).

Source: Own estimations

28 As outlined above, a weakly exogenous market is not sufficient to justify the use of bivariate models. Only if "we were to find both a single exogenous state and all other locations responding only to error correction terms involving this exogenous state" (González-Rivera and Helfand, 2001), a bivariate approach would be justified. The second condition is not fulfilled in our case.

3.4.3 Comparison of multivariate with bivariate VECM results

To gain insights into the differences between a bivariate and a multivariate approach, we estimate three bivariate $VECMs$, each containing the GASC tender price and the wheat export price observed in Russia, France and the USA, respectively (Table 6).[29] We find the long-run price transmission elasticities obtained from the multivariate approach (β_1^i) presented in Table 4 to be similar in size compared to the estimates retrieved from the bivariate approach (β_1^j presented in Table 6). Results of $\chi^2\,(3)$ tests on statistical equality of the long-run price transmission elasticities ($\beta_1^i = \beta_1^j$) suggest that the respective coefficients are in no case significantly different from each other.

While the speed of adjustments coefficients obtained from the bivariate models are qualitatively similar, as well, they exhibit a downward bias compared to the multivariate models in the majority of cases. This finding is in line with a similar camparison conducted by González-Rivera and Helfand (2001), who report that bivariate models underestimate the comparable speed of adjustment coefficients in 13 out of considered 14 cases. While the estimation of bivariate models would not result in qualitatively different overall conclusions in case of this dataset, multivariate tests are still necessary to detect and potentially prevent bias resulting from misspecified bivariate models. Further, the chosen multivariate approach offers additional insights into off-diagonal adjustment processes, which provide a more comprehensive analysis of the interdependencies between competing exporters compared to bivariate models.

29 Heigermoser (2017) estimated several bivariate VECM over the period 2008 through to 2016 using a different approach to construct a regular GASC tender price series. Results regarding Russian and French exported prices are qualitatively similar. Conversely, the model estimates suggest an adjustment of the GASC tender price towards US wheat prices, which stands in contrast to results presented in Table 6.

Table 6: Bivariate VECM estimations

	Russia-GASC	France-GASC	USA-GASC
Price transmission elasticity (PTE), β_1^j	0.891 [0.038]	0.891 [0.045]	0.950 [0.085]
Constant term (β_0^j)	0.659 [0.209]	0.664 [0.244]	0.387 [0.461]
Speed of adjustment GASC	-0.041 [0.130]	0.383*** [0.111]	0.103 [0.082]
Speed of adjustment Exporter	-0.477*** [0.118]	-0.015 [0.111]	-0.219** [0.104]
Equality of bivariate and multi-variate PTE estimates ($\beta_1^i = \beta_1^j$)	(0.837)	(0.891)	(0.690)

Note: Three lags are included in each VECM. Lag-adjusted sample runs from November 2011 to June 2019. ***, ** and * denotes statistical significance at the 1%, 5% and 10% level. Standard errors in []. P-values in ().

Source: Own estimations

3.4.4 Impulse-response analysis

As a direct interpretation of the adjustment coefficients obtained from multivariate cointegrated systems can be difficult, impulse response functions (IRF) can provide a straightforward visualization of the interrelations between the considered variables (Lütkepohl and Reimers, 1992, Lütkepohl and Saikkonen, 1997). Within an impulse response analysis, the response of an individual variable to a shock in another variable is presented relative to a baseline scenario, where the system is not affected by any shock (Koop et al., 1996). Following a convention outlined by Lütkepohl and Reimers (1992), the effect of a variable shock is considered temporary if it reverts to zero, while the effect is considered permanent if the affected variable stabilizes at a new equilibrium in response to the initial shock. While permanent effects are common in cointegrated autoregressive systems like $VECM$, the impulse responses obtained from classic vector autoregressive (VAR) systems are expected to revert to zero, i.e. to be temporary (Naka and Tufte, 1997).

One important shortcoming of standard IRFs is that they require the imposition of an ordering of the considered variables. This ordering determines the temporal sequence by which each variable can affect other variables within a multivariate autoregressive system. However, within our analysis any ordering of the considered price series appears arbitrary, while the results obtained from an impulse response analysis can vary considerably depending on the chosen ordering.[30] Addressing these shortcoming of standard orthogonalized IRFs, Pesaran and Shin (1998) propose generalized impulse response functions (GIRF). GIRFs do not require an ordering of the variables and produce one unique set of impulse responses, which is invariant to any ordering of the variables (Ihle et al., 2012). Due to this advantage, we opt to present GIRF in the following.

Figure 12 displays the responses of each variable to unit shocks of one standard deviation originating from the four considered market locations over a time horizon of 20 months. Most notably, shocks originating in the Russian market have a temporary effect on the other prices, which reverts to zero after six months. By contrast, price shocks originating in all three other market locations show permanent effects, as prices settle at new equilibria, around eight months after the initial shocks. Typically, the responses of all four prices stabilize at similar values in the long-run, while often showing similar patterns also in the short-run. The US-SRW price, however, shows more distinct short-run responses to shocks originating in Russia and France, compared to the other responses. Conversely, shocks originating from the US market prompt rapid responses in the other market locations, which settle at new equilibria already two months after the shock. However, compared to shocks originating in the GASC and the French markets, these new equilibria are considerably lower than the initial shock in the US price. These findings likely result from the minor share of US wheat on the GASC wheat tender market relative to its share on the overall world wheat market (see Table A4). Further, quality differences might play a role, as the majority of wheat exported from the USA is hard wheat, while Russia and France export soft wheat, which better meets the quality requirements set in GASC tenders. It is worth underlining that our results only apply to the global market for soft wheat.

30 In a case of $n = 4$ variables, there exist $n! = 24$ possible orderings of the variables. For each of the four considered variables there are thus six sets of responses to an initial shock, while there is no clear guidance on which ordering is appropriate in the considered case.

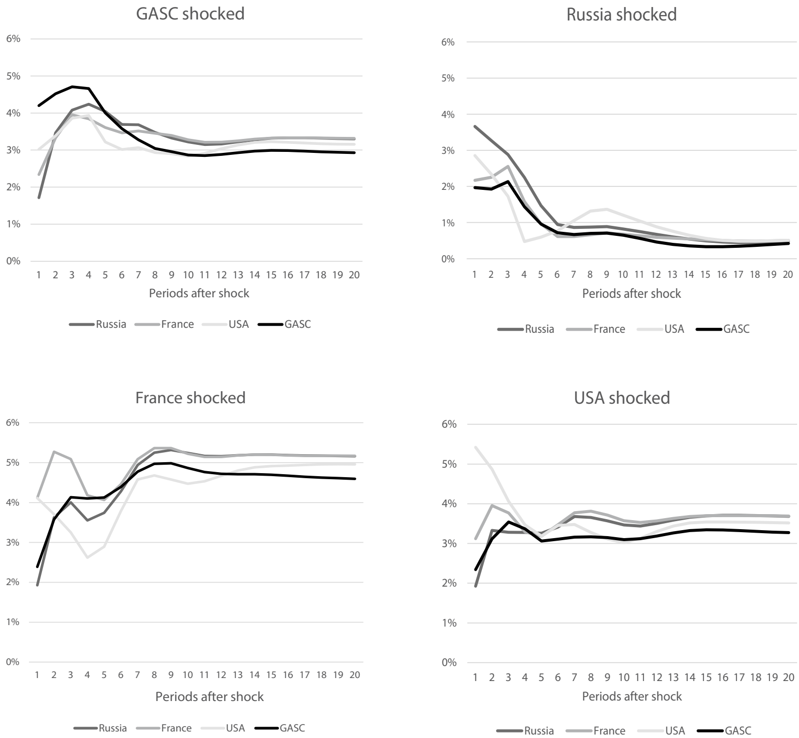

Figure 12: Generalized impulse responses to a unit shock

Source: Own estimations

3.5 SUMMARY AND CONCLUSIONS

This study on international wheat market integration is unique in considering the prices at which the Egyptian GASC purchases large amounts of wheat within its tender system. Building on a transaction-specific dataset on GASC tenders for the time period of July 2011 through to June 2019, results of the multivariate cointegration analysis suggest that Russia, France and the USA, the three largest wheat exporters worldwide, are strongly cointegrated with the GASC tender price. Conversely, Ukraine, Argentina, Kazakhstan, Canada and Australia cannot be included in the multivariate cointegration framework. We find the LOP to hold in the GASC tender market, indicating that price changes are fully transmitted between market locations. The impulse response analysis has made evident that GASC tender prices play a key role in price discovery on international wheat markets, which research disregarding this tender data might have missed.

The speed of adjustment estimates retrieved from the $VECM$ suggest strong interdependencies between the GASC tender price and the export prices from the two most important suppliers to the GASC, Russia and France. Disequilibria with the GASC tender price are corrected fastest by the Russian wheat price, while the speed of adjustment is low and statistically not significant for the French export price. The GASC tender price itself only adjusts to restore the long-run price equilibrium it shares with the French export price. Moreover, the Russian (French) export price shows substantial statistically significant error correction behavior to deviations from the equilibria between the French (Russian) export price and the GASC tender price, which suggests strong competition between the two major exporters. We find that US-SRW wheat prices solely adjust to the GASC tender price, and at a rather low speed, which can be interpreted as evidence for US price leadership. However, our results also do not provide evidence for significant adjustment of wheat export prices neither in Russia nor in France towards US prices, which does not support leadership of US prices in the system. We attribute these findings to the fact that the USA has a relatively small share in the GASC tender market.

Further, the GASC imports soft wheat, which is the type primarily exported from Russia and France, while the USA predominantly exports hard wheat.

Although Russia is the most important supplier of wheat to Egypt and the largest exporter worldwide, tests for weak exogeneity of single market locations provide evidence for price leadership of French export prices, as well as US export prices to a lesser extent. This finding is supported by the impulse response analysis suggesting temporary effects of shocks originating on the Russian wheat market. We interpret the price leadership of the French export price as an indication that Russian wheat traders use French export prices, which are transparently discovered at the Euronext commodity futures exchange in Paris, as a reference when submitting price offers in GASC wheat tender. Overall, our findings are in line with the study by Janzen and Adjemian (2017), finding that the Euronext wheat futures market recently has gained importance in international wheat price discovery versus the CBoT, as it better reflects supply fundamentals in the Black Sea region.

The chosen multivariate cointegration approach, comprising the wheat export prices of Russia, France, and the USA and one single import price, namely the GASC tender price, has proven particularly suitable to depict the GASC tender market. This is reflected in the high conformity of the transportation costs implied in the model intercepts with the observed freight costs, given unity of the long-run price transmission elasticities. This conformity also suggests that quality differences between the considered wheat prices are minimal.

The comparison of the estimated parameters of the multivariate and the bivariate *VECMs* shows that the price transmission elasticities and speed of adjustment coefficients retrieved from both approaches are qualitatively similar. The bivariate approach is, however, more limited, as the multivariate framework offers additional insights into adjustments between prices from different exporting countries that compete on the GASC tender market.

The results of this analysis only partly support the price leaderhsip of US prices in the international wheat markets identified by Ghoshray

(2006). Also, the finding by Heigermoser (2017) that tender prices adjust to US export prices is not supported. However, this study employed a different approach to constructing a continuous tender price series. Moreover, our findings do not confirm Goychuk and Meyers (2014) in suggesting that Russian export prices lead French and US wheat prices. However, the above-mentioned studies investigated price relationships for earlier time periods. We therefore assume that our findings referring to the time period 2011 thorugh to 2019 reflect the changes in the international wheat market that resulted from the rising importance of Russia and the Black Sea region in general.

4 BLACK SEA SPOT AND MAJOR FUTURES PRICES: REALIZED VOLATILITY RELATIONS[31]

31 An earlier version of this chapter was published in the conference proceedings of the 59th Gewisola Annual Meeting (see Heigermoser et al., 2020).

Over the past two decades, the physical wheat trade underwent a fundamental restructuring. The Black Sea exporters Russia, Ukraine and Kazakhstan increased their joint share in global wheat exports from around 12% in the early 2000s to one third recently, while the US share in global exports halved from more than one quarter in the early 2000s to around 13% in recent seasons (see also Figure 1). However, as the physical wheat trade shifts from North America to Europe and the Black Sea region, the grain futures market landscape appears rather stable. Wheat futures contracts traded at US exchanges such as the CBoT or the Kansas City Board of Trade (KCBoT) remain most actively traded. While recent research has suggested that the EPA wheat futures contract is gaining importance for global wheat price discovery, its trading volumes still remains minor compared to competing US markets (Janzen and Adjemian, 2017). A futures market that genuinely represents wheat markets in the Black Sea region, the novel center of physical wheat trade, does not yet exist. Several attempts by leading commodtiy futures exchanges to establish such a Black Sea wheat contract have either failed to remain in initial stages. As a result, Black Sea market participants use established US or EU wheat futures contracts as risk management tools to hedge their price risk, which can have adverse consequences (see Financial Times, 2017b).

The holder of a wheat futures contract is obliged to deliver or receive the specified commodity at a pre-defined location during a specific time in the future.[32] Quantity and quality of the traded grain are precisely defined, and the contracts are cleared via an exchange. Futures markets have lower transaction costs compared to physical market (Working, 1962) and new information can thus be incorporated quickly, which is key to price discovery (e.g. Morgan, 1999). To further function as an effective risk management tool, the price of a futures contract must co-move with the spot price on a physical market. If this is the case, a market

32 In practice, only a tiny number of futures contracts are actually executed. Most contracts are settled prior to their expiry, i.e. their last trading day. However, the delivery mechanism ensures that the futures price converges to the spot price at the specified delivery location as the contract reached maturity (Vollmer et al., 2021).

participant can enter a futures market position to transform flat price risk on the physical market (i.e., the risk of a change in the price level) into basis risk, which is typically smaller (Vollmer et al., 2021). A loss (profit) on the physical market occurring over the holding period of the futures contract will be offset by a profit (loss) on the futures market, if the basis (i.e. the difference between the spot and the futures price) remains constant.

However, several factors can affect the basis and therefore increase the basis risk to market participants using futures to hedge price risk (Karali et al., 2018). As geographical distance between the physical market and the delivery location of the futures contract increases, changes in transportation costs can lead to a (temporal) divergence between spot and futures prices. Similarly, a change in relative availability of wheat qualities in a region (e.g. due to a weather shock) can have an impact on the basis (Vollmer et al., 2021). Especially the great geographical distance between the Black Sea spot and the world's leading wheat futures markets in the USA implies increased basis risk. This thus complicates risk management for market participants aiming to hedge price risk in the Black Sea region and can lead to losses for companies if spot and futures market prices diverge.

Against this background, we investigate the novel situation on the world wheat market focusing on the following research questions: (How) does the ascent of the Black Sea exporters affect the global wheat futures market landscape? How can interdependencies between Black Sea spot and major futures markets be characterized? Do futures markets drive spot markets, or vice versa? Is one specific futures market more important regarding price formation on Black Sea wheat markets? As previous studies have suggested imperfect competition in the Russian export sector (Uhl et al., 2016, Pall et al., 2013, Gafarova et al., 2015), we further extend the view to exchange rate pass-through,[33] analyzing how the ruble foreign exchange market affects the considered wheat markets and whether asymmetries in this relationship can be determined.

33 Following Gervais and Khraief (2007) we define exchange rate pass-through as the export price movement following changes in exchange rates.

As spot and futures prices typically refer to different delivery periods, an investigation focusing on price relationships in levels requires the construction of a spot-equivalent futures price series (Vollmer et al., 2020). However in this study, we follow an alternative approach and analyze relationships between Black Sea spot, and CBoT and EPA futures markets not in price levels but in price volatility. Precisely, we investigate interdependencies between series of realized variance *(RV)* within an vector autoregressive *(VAR)* framework, following similar approaches by Brümmer et al. (2016a) and Dalheimer et al. (2017). To assess asymmetric responses to ruble depreciations or appreciations, we include signed jumps (Patton and Sheppard, 2015) as exogenous variables into our *VAR* model, in an approach similar to Karali and Power (2013).

This chapter is organized as follows: in section 4.1, we provide a brief literature review. Background information regarding the establishment of futures markets for Black Sea wheat is presented in section 4.2. The price data used in the empirical analysis and our methodological approach are described in sections 4.3 and 4.4, respectively. Subsequently, estimation results are reported and discussed in section 4.5, before conclusions are provided in the final section.

4.1 LITERATURE REVIEW

The majority of research analyzing the relationship between agricultural spot and futures prices focuses on US markets for storable commodities. Arnade and Hoffmann (2015) investigate US soybean and soybean meal price relations, finding that futures tend to lead spot markets. However, this relationship can weaken in periods of high futures price volatility as observed in 2005 through to 2013. These findings are in line with Peri et al. (2013), who confirm that CBoT corn and soybean futures prices, which are more liquid and can rapidly incorporate new information, generally lead physical spot prices. The latter can, however, gain in importance for price discovery in crisis periods. Karali et al. (2018) explicitly focus on nonconvergence in spot and futures prices for US soft red winter (SRW) wheat, which occurred in 2008 and 2009. They determine the specification of specific futures contracts as a main reason explaining failures to converge.

Compared to research considering US commodity markets, studies analyzing spot-futures price relations on European agricultural markets are generally rare. Regarding Black Sea markets, no such relationship has been analyzed thus far to the best of the authors' knowledge. Vollmer et al. (2020) investigate price level relationships between German wheat spot and EPA futures markets between 2002 and 2016, using a price discovery methodology. Their findings indicate that EPA prices generally lead the considered spot prices, except for periods of high price volatility. These findings are in line with Adämmer and Bohl (2018), who focus on European wheat, corn and canola spot and futures markets employing a similar approach. Investigating global maize spot markets with weekly price data, Arnade und Hoffmann (2019) find that US prices tend to lead in price discovery, while the importance of Ukrainian export prices increases particularly in periods of elevated exports.

Several further studies focus on price leadership between various futures markets, where substitutable commodities are traded. Janzen and Adejmian (2017) analyze price discovery and leadership among three major wheat futures markets in the USA, as well as the EPA. They find that the CBoT, which is the most liquid among the considered markets, generally leads in global wheat price discovery. However, their results also suggest that the EPA is gaining importance especially after 2010, which the authors attribute to the increasing significance of the Black Sea region. Besides price discovery analyses, numerous studies have also focused on volatility spillovers between different futures markets. Employing a multivariate generalized autoregressive conditional heteroscedasticity *(MGARCH)* model framework, Hernandez et al. (2014) suggest strong spillover effects between corn, wheat and soybean markets and determine the CBoT as leading futures exchange. Focusing on North American and European wheat futures exchanges, Yang et al. (2003) find rather minor intercontinental spillover effects and no clear price leader among the studied markets. Gardebroek et al. (2016) find that volatility transmission among various US commodity futures markets can be determinied particularly when investigated at lower-than-daily frequencies.

After food price crises occurring in 2007/08, as well as 2020/11, considerable research has focused on identifying factors driving food price volatility. A comprehensive review of strands of literature focusing on specific volatility drivers can be found in Brümmer et al. (2016b). Furthermore, the debate within agricultural economics regarding the role of speculation in the recent food crises is presented in detail by Pies et al. (2013). Among numerous potential drivers, the effect of exchange rate movements on food price volatility has been considered by several studies. Karali and Power (2013) evaluate factors affecting numerous US commodity markets including grain markets and find that volatility is particularly responsive to appreciations of the US dollar, while depreciations have a smaller effect. Brümmer et al. (2016a) investigate several potential drivers of volatilty on oilseeds and vegetable oils markets. They identify volatility in the US dollar exchange rate as a central factor regarding most considered agricultural markets. This finding is in line with Jumah and Kunst (2001), who focus on coffee and cocoa futures markets and determine exchange rate volatility as major source of commodity price volatility. Similar effects are also reported in Ott (2014).

While we investigate the effect of signed jumps in the ruble versus US dollar exchange rate as exogenous driver, we further control for asymmetric effects. Asymmetric responses could result from imperfect competition in the Russian wheat export sector. Previous studies analyzing pricing-to-market behavior of Black Sea wheat exporters have found evidence for price mark-ups in the considered grain export sectors (Uhl et al., 2016, Gafarova et al., 2015, Pall et al., 2013). These findings suggest that Russian wheat exporters exert market power to price discriminate between different export markets by transmitting changes in respective exchange rates only selectively.

4.2 DEVELOPMENT OF A FUTURES MARKET FOR BLACK SEA WHEAT

While climatic conditions in the Black Sea region generally favor wheat production, the region is also characterized by high risk of extreme weather events (Liefert et al., 2010). In season 2010/11, drought and wildfires in key production regions diminished the Russian wheat crop by one third (USDA, 2021a). This harvest shortfall prompted the Russian government to ban all grain exports from early August 2010, which contributed to a food price crisis in 2010/11 (Götz et al., 2013a, 2016a). Janzen and Adjemian (2017) argue that the EPA futures market gained in importance in this period because it better reflected supply and demand information regarding the Black Sea region. Consequently, the question concerning a futures market specifically reflecting Black Sea wheat also became more urgent after season 2010/11.

The Chicago Mercantile Exchange (CME) was first to introduce a genuine Black Sea wheat futures contract (ticker symbol: BSW) in June 2012 (Reuters, 2012). Like the traditional CBoT soft red winter (SRW), or EPA No. 2 milling wheat futures contracts, the BSW derivative was based on physical delivery to Russian, Romanian or Ukrainian Black Sea ports. However, the BSW contracts were barely traded and did not attract sufficient liquidity, which is a key factor determining the effectiveness and thus the success of a futures contract (Garcia and Leuthold, 2004). Market participants attributed the contract's failure to the incalculable risk of ad hoc export restrictions, as well as to frequent logistical bottlenecks at Black Sea ports. Such circumstances would render physical delivery or receipt impossible and thus leave the contract holder unable to fulfill contractual obligations. Further, market participants pointed to the heterogeneity of wheat classes traded at the specified delivery locations, and criticized unacceptable uncertainty concerning the wheat quality requirements underlying the BSW contract.

In 2016, the EPA initially communicated that it also planned to establish a Black Sea wheat futures contract (Reuters, 2016c). Three days later, the CME responded to the announcement of its competitor and adjusted the specifications of its BSW contract, excluding the port of Sevastopol as delivery location. However at this point, the BSW contract had already been suspended for two years due to violent conflict in Eastern Ukraine (Reuters, 2016b) and the change did not lead to increased trading activity.

As Russia became the world's largest wheat exporter in 2017/18, an effective futures market for Black Sea wheat was still nonexistant. The risk resulting from the usage of traditional US futures markets to manage Black Sea price risk became clearly apparent in 2017. Regarding its third quarter earnings, Archer-Daniels-Midland (ADM), one of the world's largest commodity trading firms, attributed a loss of 20 million USD to a 'lack of correlation' between hedges off 'North American [futures] exchanges' and the 'underlying movement' on Black Sea wheat and corn spot markets (ADM, 2017). Concerning this time period, Figure 13 shows a considerable change in basis between Russian wheat export and CBoT futures prices. While the CBoT futures prices remained 20 USD/t below the Russian spot price throughout 2016/17, it rapidly rose to exceed it in early July 2017, before reverting to the previous basis by August.[34] Due to this sudden, unexpected divergence, ADM's losses in the one market were likely not offset by gains in the other, contributing to the company's loss in the respective quarter. This consequential divergence clearly underlines the potential benefit of a functioning Black Sea wheat futures market, which could track price movements on physical market more closely.

34 The Australian grain cooperative CBH Group reported a loss due to similar divergence between Australian spot and US futures wheat prices in December 2019 (Financial Times, 2019a).

Figure 13: Russian wheat export prices and CBoT, EPA futures

Note: EPA prices are originally denoted in EUR/t and are converted to USD/t using exchange rates provided by the ECB (2019). CBoT prices are originally denoted in ct/bushel.

Source: Own illustration based on S&P Global Platts (2019) and AHDB (2019)

In the same year, the CME launched a second, differently specified Black Sea futures contract on December 18, 2017 (ticker symbol: BWF, Reuters, 2017a). Responding to previous criticism, this novel derivative is not based on physical delivery. Rather, the BWF contracts are swaps that are financially settled against a USD-denoted spot price index provided by a price reporting agency. The underlying price index reflects one key export market location, namely the Russian port of Novorossiysk. Quality requirement, loading window and cargo size correspond to common specifications in the Black Sea region. Options trading to this contract was introduced in July 2018 (Reuters, 2018a). While volume and open interest remain negligible compared to the established CBoT or EPA futures markets, the BWF contracts are actively traded to date (Wall Street Journal, 2018, CME Group, 2021). Due to the relative success of the BWF swaps, the CME ultimately delisted the BSW contract in March 2019 (CME Group, 2019).

The BWF contracts reflect spot prices at a key export location and are therefore useful to the export sector. However, because they are denoted in USD, they are rather impractical for Russian wheat producers conducting their business operations in rubles, as the usage of a risk management instrument denoted in a different currency will necessarily expose a producer to additional exchange rate risk (Dawson, 2015). In view of this shortcoming, the Moscow Stock Exchange (MOEX) introduced a wheat futures contract denoted in rubles in December 2020, aiming to cater to Russia's domestic market. The MOEX derivative is based on physical delivery and replaces a financially settled swap contract, which was discontinued in August 2018 due to alleged theft of grain from leased warehouses (AgriCensus, 2019). In late 2020, the EPA also reaffirmed its intention to establish its own Black Sea futures contract. Precisely, it announced to launch a financially settled swap contract representing Ukrainian durum wheat in the second half of 2021 (Reuters, 2020b).

Leading commodity futures exchanges compete to establish a functioning (i.e., sufficiently liquid) Black Sea wheat futures market. Given the region's increasing importance as global production center, such a derivative could potentially serve as pricing benchmark for the world wheat market in the future. While a functioning Black Sea wheat futures contract would foster transparency and facilitate price discovery and risk management in the region, the establishment of a trusted, consistently liquid futures market takes considerable time (Garcia and Leuthold, 2004). When establishing the first Black Sea wheat futures contract in 2012, the CME stated that it aimed to position itself 'for the long run' (Agrimoney, 2012).

4.3 DATA AND DATA PREPARATION

Our econometric analysis builds on the spot price index representing Russian soft winter wheat that is used as a settlement price for the CME's BWF contract (see Table 7 and Figure 13). The price index is recorded each business day by the price reporting agency S&P Global Platts (2019). The agency's price assessment is based on current price bids and offers collected from traders, brokers, millers, farmers and processors. Price quotes referring to different cargo sizes, wheat qualities, export locations, and loading windows are converted to represent free on board (FOB) export prices for a 25,000-ton supramax vessel size of Russian 12.5% protein soft wheat loaded at the port of Novorossiysk between 28 and 41 days in the future.[35] S&P Global Platts initially recorded the Russian export price index on March 17, 2014. The index was first used to settle a forward contract traded without the involvement of an exchange in March 2017 (Financial Times, 2017a) and serves as settlement price for the exchange-cleared BWF swap contract since December 2017.

Table 7: Price series used in VAR-X analysiss

Price series	Specification	Source
Black Sea spot	FOB spot price index Novorossiysk, USD/t	S&P Global Platts (2019)
CBoT SRW futures	Closing price of nearest contract, ct/bsh	AHDB (2019)
Euronext No. 2 milling futures	Closing price of nearest contract, EUR/t	AHDB (2019)
Russian ruble FX	Average weighted rate, rubles/USD	Bank of Russia (2019)

Note: Russian ruble rates refer to 'tomorrow' settlements. bsh denotes 'bushel' (37 bushel equal one ton).

Source: Own illustration

35 Further details on the specification underlying the Russian wheat price assessment can be found in the specification guide provided by S&P Global Platts (2020).

Regarding futures markets, we consider CBoT No. 2 SRW wheat, as well as the EPA No. 2 milling wheat prices (AHDB, 2019, see Table 7). Due to its high liquidity, the CBoT is widely considered as global wheat pricing benchmark. The EPA is included as recent research has suggested that it is closer related to Black Sea wheat markets (Janzen and Adjemian, 2017, Heigermoser et al., 2021).

Futures price series are discontinuous in nature, as an individual futures contract can only be traded until its delivery period, when it expires. However, time series analyses typically require continuous price series, ideally spanning multiple years. We therefore concatenate series of daily closing prices representing subsequent nearest futures contracts and use backward proportional adjustment to prevent artificial price jumps at transition dates (Carchano and Pardo, 2009, Masteika et al., 2012). This preparation procedure is illustrated in Figure 14, which depicts price series of four subsequent EPA contracts. The contracts refer to the delivery periods December 2017, as well as March, May and September 2018. At any point in time, the contract that is closest to expiry (denoted 'E' in Figure 14) is called the 'nearest' contract. Typically, nearest contracts are most actively traded, i.e. show the highest trading volume.[36] However, in the weeks directly preceding expiry, when positions are settled or transferred to contracts representing later delivery, the nearest futures lose liquidity (Figure 15). During these periods, erratic price changes can occur, as observable in the last trading days of the March 2018 contract (prior to 'E2' in Figure 14). To avoid including these pre-expiry periods, we set the transition dates between nearest and second nearest contract (denoted 'T' in Figure 14) one month prior to expiry of the former, following similar approaches by Adämmer and Bohl (2018) and Arnade and Hoffmann (2015).

36 Current open interest and volume statistics for the CBoT and EPA wheat futures contracts can continuously be examined for example on the Kaack website (2021).

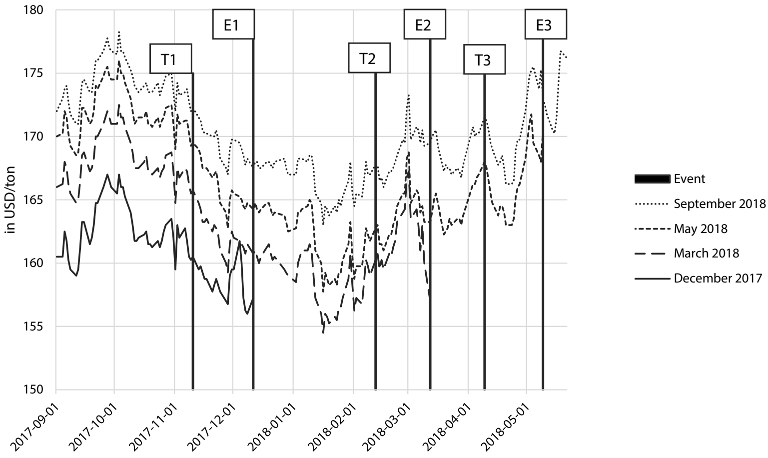

Figure 14: Illustration of proportional futures series adjustment

Note: Lines refer to futures price series for futures contracts referring to different delivery periods. On transition dates denoted with 'T', we switch from nearest to second-nearest price series to construct a continuous futures price series (see section 4.3). Dates denoted with 'E' represent the expiry (i.e. the last trading day) of the respective futures contract.

Source: Own illustration based on AHDB (2019)

Any transition between two futures contracts introduces an artificial price shift on the respective date (Carchano and Pardo, 2009). To exemplify, on transition date 'T1' an unadjusted EPA futures price series would exhibit and increase of 3.4% from 160.50 EUR/t (the last considered price of the December 2017 contract) to 165.75 EUR/t (the first considered price of the following March 2018 contract). However, this price change clearly does not reflect new supply or demand information. We use proportional adjustment techniques to avoid such artificial price jumps (Masteika et al., 2012). Starting with the respective latest futures contract in the sample, at each transition date the ratio between the nearest and its preceding contract is calculated. This ratio is used as a factor to shift the nominal prices of all preceding contracts. Regarding the example presented in Figure 14 at 'T3' we calculate the ratio between the closing price of the September 2018 and the May 2018 contract (1.0358) and shift all nominal prices of the May 2018 including at 'T3', as well as prices for all previous contracts by this ratio. Progressing backwards, this procedure is repeated at each transition date. The earliest EPA contract in our sample (May 2014) is thus shifted 21 times, as there are 22 EPA contracts considered in our sample.

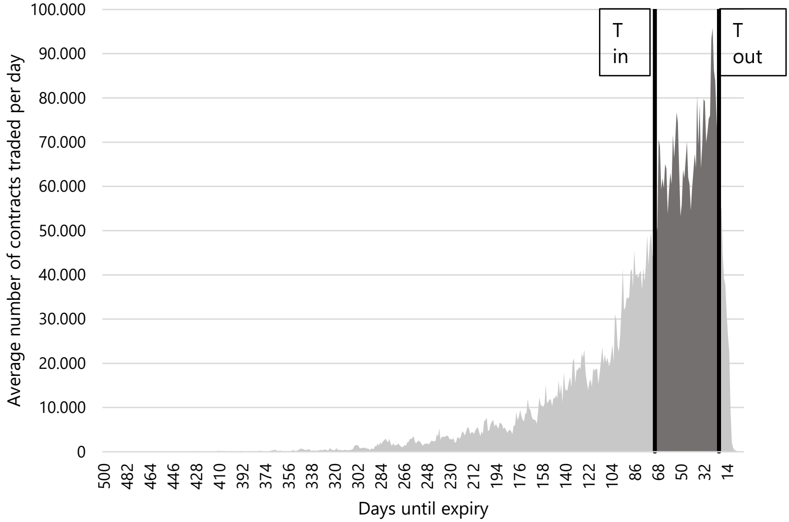

Figure 15: Average daily trading volume of nearest CBoT contracts over life cycle

Note: Dark shaded area represents period considered in continuous futures series. Average volume per day calculated from nine subsequent contracts (May 2018 through to December 2019). 'T in' ('T out') indicate the transition date we chose for entering (exiting) the second nearest (nearest) contract.

Source: Own illustration based on AHDB (2019)

Following this procedure, the resulting backward ratio-adjusted CBoT and EPA futures price series will exhibit incorrect price levels for all but the latest contract (see Figure A5 in the appendix for a direct comparison between adjusted and unadjusted futures price series in levels). However, the ratio-adjusted series are free from artificial price jumps at rollover dates and will therefore produce accurate price return series (i.e., relative price changes from one day to the next) throughout the period of investigation.[37] This proportional adjustment approach is superior in our case as we consider spot-futures relationships not in levels but in realized volatility, which is solely based on price return series.[38]

To investigate the effect of currency movements, Russian ruble (RUB) exchange rates are further considered in our analysis (Bank of Russia, 2019). Wheat prices within Russia are typically quoted in ruble, while export prices are denoted in USD, the currency that most international grain trade relies upon (Brümmer et al., 2016a). As this study focuses on one specfic physical market (Russia), it is advantagenous that real exchange rates can be used to analyze exchange rate pass-through. We can thus complement previous research focusing on US markets, which typically employed trade weighted USD strength indices aggregated from various exchange rates (e.g. McPhail et al., 2012, Karali and Power, 2013).

Our period of investigation ranges from March 17, 2014, when the Black Sea export price index was first recorded, through to June 14, 2019, comprising 1354 observations. Due to holidays, Black Sea, CBoT and EPA price series exhibit 2.4%, 2.4% and 1% of missing observations, respectively, which we fill using linear interpolation.[39] Euro-denoted EPA futures prices are converted to USD using daily exchange rates provided by the European Central Bank (ECB, 2019). A large price decrease of 8.8% in the Russian wheat price index in mid-June 2014 (see Figure 13) resulted from a full shift of the assessment period from the 2013/14 to the 2014/15 crop over a weekend. As this unusually large price return thus stems from the technicalities of the price assessment procedure, it is excluded from the following analysis. We further exclude three exceptionally large returns

37 A further advantage of proportional adjustment techniques is that the adjusted price series cannot turn negative, which is possible if non-proportional adjustment techniques are employed (Masteika et al., 2012).

38 All following estimations were additionally conducted using unadjusted futures price series, containing artificial price jumps.

39 We additionally conduct the following estimations using series which only include days when all considered time series exhibit values, resulting in a sample of 1291 observations. The results remain largely unaffected.

in the ruble exchange rate series occurring on December 16, 18, and 20, 2014 due to central bank intervention.[40]

4.4 METHODOLOGY: THE VAR-X APPROACH

We use daily series of Russian spot price indices and adjusted wheat futures prices to construct realized, as well as conditional volatility series. Based on the theory of quadratic variation (Andersen, et al., 2003, Barndorff-Nielsen and Shepard, 2002, McAleer and Medeiros, 2008), realized variance *(RV)* is defined as the sum of squared intra-period price returns. As opposed to *GARCH* (Bollerslev, 1986) approaches (see below), the *RV* approach is non-parametric. The *RV* estimator can be written as:

$$RV_t = \sum_{j=1}^{N} r_{t,j}^2 \tag{2}$$

where RV_t denotes the *RV* in period *t*, which is calculated from *N* squared intra-period autocorrelation-free price returns, $r_{t,j}^2$, with $j = 1, 2, \ldots, N$. Price returns are defined as $r_t = p_t - p_{t-1}$, where p_t is a level price series expressed in natural logarithm form. Returns thus represent relative price changes from period $t-1$ to period *t*. The computation of *RV* necessarily implies a shift to a lower data frequency. In our case, we calculate weekly *RV* measures based on daily price series. Each individual weekly *RV* measure is thus calculated from five price returns, including one over-weekend return ($N = 5$).[41]

40 Following Poon and Granger (2005), we additionally truncate abnormal ruble returns to not exceed six standard deviations of the whole return series. Results are qulitatively similar.

41 Throughout our period of investigation, 17 weekly RV measures (6%) are calculated from only four daily returns. We control for this in the following estimations using a dummy variable indicating weeks with fewer returns.

Thus far, RV approaches are rarely employed in the agricultural economics literature.[42] We therefore additionally estimate conditional variance (CV) using standard $GARCH$ models (Bollerslev, 1986) to provide a comparison between the two approaches to estimating volatility. Regarding CV, a $GARCH(1,1)$ is the model specification most commonly used (Hansen and Lunde, 2005). It can be written as:

$$CV_t = \omega + \alpha u_{t-1}^2 + \beta CV_{t-1} \tag{3}$$

where CV_t is the conditional variance at period t, with $t = 1, 2, \ldots, T$. CV_t is estimated as a function of its past values, as well as squared lagged innovations from an underlying, autocorrelation-free return series u_t, where $u_t = \epsilon_t \sigma_t$, with $\epsilon_t \overset{iid}{\rightarrow} D(0, 1)$. Here, $D(0, 1)$ represents a distribution that is i.i.d. with mean zero and variance one. ω represents a constant term. As volatility cannot be negative, the α and β coefficients are restricted to positivity. Further, imposing that $\alpha + \beta < 1$ ensures stationarity of the estimated CV series. As opposed to the RV estimator, CV can be estimated at the same frequency as the underlying return series. However, to also provide a direct comparison with weekly RV measures, we estimate CV_t using weekly (CV_t^w), as well as daily (CV_t^d) return series. Weekly returns are constructed as relative changes between prices recorded at the last business days of subsequent weeks. A drawback of conditional variance estimation using parametric $GARCH$ models is that the estimation using maximum likelihood requires the researcher to assume a specific return distribution, which is not necessary using the model-free RV estimator.

To investigate asymmetric volatility responses to exchange rate appreciations and depreciations, we build on the concept of signed jumps proposed by Patton and Sheppard (2015). Signed jumps can be calculated as the difference between positive and negative realized semi-variances (RSV, see also Barndorff-Nielsen et al., 2010, Andersen et al., 2007), which are computed as follows as follows:

42 Recent exceptions focusing on realized volatility estimated from high frequency data from agricultural futures markets include Couleau et al. (2018), Bunek and Janzen (2015), as well as Degiannakis et al. (2020).

$$RSV_t^+ = \sum_{j=1}^{N} r_{t,j}^2 \, I\{r_{t,j} > 0\}$$

$$RSV_t^- = \sum_{j=1}^{N} r_{t,j}^2 \, I\{r_{t,j} < 0\} \qquad (4)$$

While generally similar to the computation of RV from equation (2), positive and negative realized semi-variances (RSV_t^+ and RSV_t^-) are constructed solely from positive and negative price returns, respectively. The two RSV measures provide a full decomposition of RV, implying that $RV_t = RSV_t^+ + RSV_t^-$ (Patton and Sheppard, 2015). Based on this decomposition, a series of signed jumps can be defined as:

$$J_t = RSV_t^+ - RSV_t^- \qquad (5)$$

where J_t represents a signed jump at period t, which will exhibit a positive value if $RSV_t^+ > RSV_t^-$ and vice versa. The sign of J_t will give an indication into whether the price mostly moved upwards or downwards within period t and is thus closely related to straightforward price returns constructed for the same frequency.[43]

To investigate interdependencies between spot and futures wheat price volatility, as well as asymmetric responses to exchange rate movements, we estimate a vector autoregressive model with exogenous variables (VAR-X) following similar approaches by Brümmer et al. (2016a), Dalheimer et al., (2017) and McPhail et al. (2012). Building on seminal research by Sims (1980), a $VAR(p)$-$X(q)$ model framework can be used to estimate the dependency of K endogenous variables on p lagged observations of all K endogenous, as well as q lags of exogenous variables. Our $VAR(p)$-$X(q)$ model can formally be written as:

$$RV_t^k = \alpha^k + \sum_{m=1}^{M} \sum_{i=1}^{p} \beta_{m,i}^k \, RV_{m,i-1}^k + \sum_{j=1}^{q} \gamma_j^k J_{t-1} + \sum_{j=1}^{q} \theta_j^k D_{t-1} + \sum_{s=1}^{S} \eta_s^k Z_{s,t} + \varepsilon_t^k \qquad (6)$$

43 The correlation between jumps and weekly returns is 0.92 regarding ruble exchange rates.

where RV_t^k denotes the weekly RV of endogenous variable k at week t, with $t = 1, 2, ..., T$ and $k = \{rus, cbot, epa\}$. α^k refers to the constant term of the equation of endogenous variable k. The $\beta_{m,i}^k$ coefficient represents the estiamted effect of the m^{th} RV variable, with $m = 1, 2, ... , M$ and $M = K = 3$, lagged by i periods, with $i = 1, 2, ... , p$, on endogenous variable RV^k. To assess potentially asymmetric effects of exchange rate movements on grain price volatility, we include a series of signed jumps, J_t, as well as a dummy variable, D_t, indicating negative jumps, lagged by j periods, with $j = 1, 2, ... , q$. In this respect, the coefficient γ_j^k denotes the estimated effect of the signed exchange rate jump at period $t - j$ on endogenous variable RV_t^k. The dummy variable D_t equals to one if $J_t < 0$ and zero otherwise. A statistically significant parameter θ^k thus indicates an asymmetric response of the k^{th} wheat price volatility to ruble appreciations versus depreciations. To account for seasonality, we include S dummy variables representing the seasons spring, summer and fall, respectively. Further, a dummy variable indicating RV measures computed from four instead of five daily returns in included, implying $S = 4$. The parameter η_s^k thus denotes the effect of dummy variable $Z_{s,t}$ on endogenous variable k, with $s = 1, 2, ... , S$. The dummy variable $Z_{s,t}$ will equal to one if the RV_t^k falls into the respective season or corresponds to a shorter week, and zero, otherwise. Finally, ε_t^k denotes an identically and independently distributed vector of residuals obtained from estimating the equation of endogenous variable k.

A significant γ_j^k coefficient indicates that a depreciation in the ruble exchange rate lagged by j periods affects the k^{th} wheat price volatility in period t. As wheat prices within Russia are denoted in ruble, while export prices are quoted in USD, we hypothesize that a depreciating ruble will enable exporters to purchase Russian wheat cheaper on the domestic market. Competition in the export sector will force exporters to transmit the decreased purchasing costs into lower dollar-denoted offer prices on international wheat markets, where they compete with exporters from other regions. Regarding potentially asymmetric effects, a significant θ_j^k coefficient indicates that a currency appreciation at period $t - j$ affects the price volatility in the k^{th} market differently than a currency depreciation. To exemplify, if γ_1^{rus} and θ_1^{rus} are both positive and significant, a currency depreciation in the previous week will affect wheat price volatility on the Russian export market but the effect of an appreciation will be larger, with the difference being statistically significant. We will interpret such asymmetric exchange rate pass-through as evidence of imperfect competition in the Russian grain sector.

With $K = 3$, $p = 3$, $q = 3$, and $S = 4$ each of the K VAR equations will have 19 parameters to estimate. Nine autoregressive parameters represent the estimated autoregressive effects of the K endogenous variables at p lags, respectively. Six parameters denote the (asymmetric) effects of the exogenous signed jump series at q lags, while four dummy variables control for seasonality and RV measures calculated from fewer returns.

4.5 ESTIMATION RESULTS

4.5.1 Wheat price volatility: comparison of realized and GARCH approaches

Realized and conditional variance is estimated from return series, which have to be free from autocorrelation. Ljung-Box tests suggest that CBoT and EPA returns series are free from autocorrelation for up to 50 lags (see Table A7 in the appendix). These markets can therefore be considered efficient. However, Russian spot prices appear to exhibit serial correlation. We attribute this finding to a large share of zero-returns of 40.4% in the respective series, suggesting that the Russian physical market can remain calm for several days without changes in price bids or offers.[44] This compares to zero-return shares of 1.4% and 6.9% for the CBoT and EPA return series, respectively (see Table A7 in the appendix). This disparity

44 Figure 13 clearly depicts periods of subsequent zero-returns in the Russian spot price e.g. in December 2014.

likely results from higher transaction and entry costs on physical market compared to futures markets. To ensure that the Russian spot price returns are autocorrelation-free, we model the series as an autoregressive moving average $(ARMA)$ process including one AR and one MA term, respectively.[45]

Weekly RV series, as well as conditional $GARCH(1,1)$ volatility estimated from weekly and daily returns are presented in Figure 16, while Table 8 provides descriptive statistics. Figure 16 confirms that volatility on futures markets is generally higher than on the Russian physical market. CBoT prices typically exhibit a higher realized volatility than EPA prices. In annualized terms, average Black Sea volatility (realized and conditional) equals to around 8%, while the mean volatility of EPA and CBoT futures prices is estimated at 16% and 25%, respectively (Table 8). This finding is in line with Janzen and Adejmian (2017) who report that the EPA futures market is "stale" compared to the more liquid CBoT. Figure 16 further provides initial indication of co-movement in the volatility series, as periods of high or low volatility coincide in the considered markets (e.g. in mid-2015 and mid-2018). However, while volatility appears elevated in summer months, clear seasonal patterns cannot be determined visually.

Visually comparing realized and conditional volatility, we can state that the RV series exhibit greater variability, especially in the short term. Thus, while the average volatility obtained from the RV and $GARCH$ approaches is similar, the RV series consistently exhibit higher standard deviations, which can be more than double compared to the respective CV series (Table 8). In line with this finding, maxima (minima) of the RV series are consistently greater (smaller) compared to the $GARCH$ volatility series regarding all considered markets.

By visual comparison, weekly and daily CV series appear similar. The descriptive statistics suggest that the daily CV series, which is calculated from a five times greater dataset, exhibits a greater standard deviation compared to the weekly series. This is particularly relevant regarding

45 The AR and MA coefficient estimates equal to 0.875 and -0.726, respectively. Both are significant at the one percent level.

CBoT futures volatility and less so regarding EPA futures. Generally, it appears that *GARCH* models still provide accurate estimates of volatility even when estimated from a smaller data set, i.e. when *CV* is estimated from weekly instead of daily returns. Finally, ADF unit root tests (Dickey and Fuller, 1979) confirm that all considered volatility series are stationary (Table 8) and can thus be investigated within a *VAR* framework.

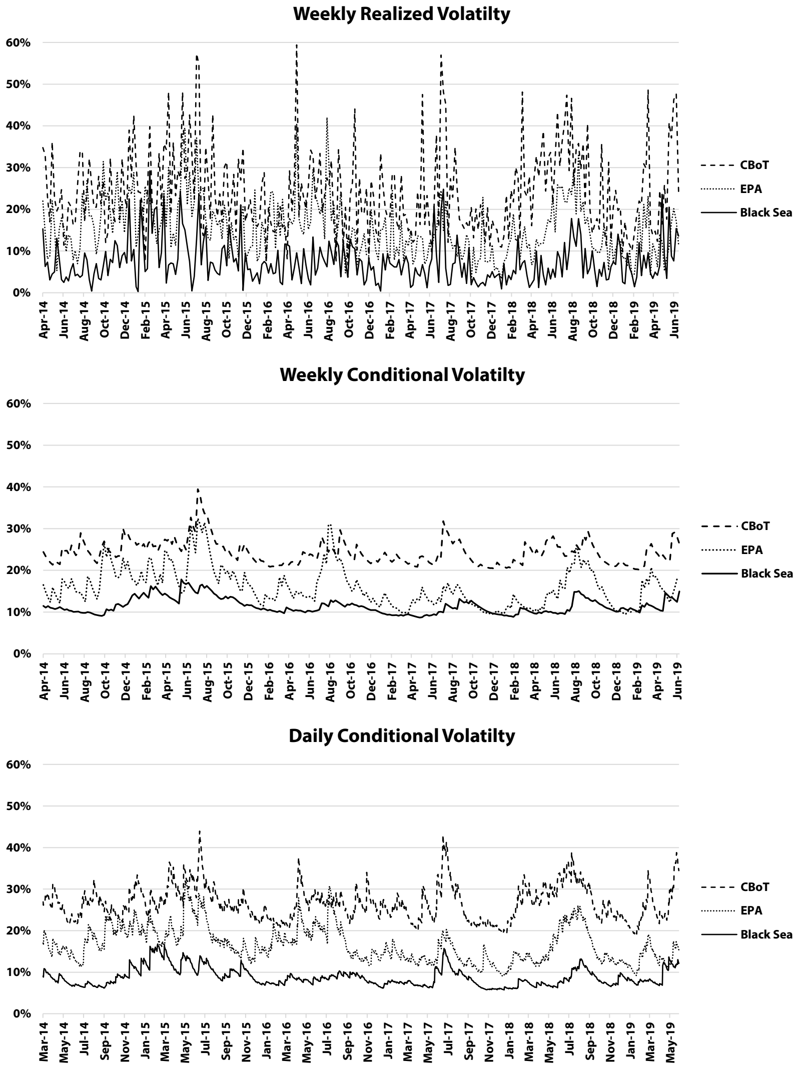

Figure 16: Wheat price volatility: Realized versus GARCH

Note: α and β coefficients from GARCH models are presented in Table 8. Weekly and daily volatility estimates are based on weekly and daily returns and are annualized by multiplying the series by $\sqrt{52}$ and $\sqrt{260}$, respectively.

Source: Own calculations

Table 8: Descriptive statistics of realized and conditional wheat price volatility

	Mean	StDev	Min	Max	Skewness	Kurtosis	N	UR test (t-statistic)	α	β	ω
		Weekly realized volatility, annualized									
Russia	0.074	0.051	0.003	0.292	1.465	2.451	274	-6.692***	--	--	--
CBoT	0.242	0.101	0.067	0.594	0.923	0.715	274	-6.229***	--	--	--
EPA	0.154	0.070	0.024	0.420	0.911	1.131	274	-6.704***	--	--	--
		Weekly conditional volatility, annualized									
Russia	0.114	0.019	0.087	0.178	1.010	0.407	273	-2.906**	0.073	0.876	0.000
CBoT	0.243	0.030	0.201	0.395	1.426	3.606	273	-4.699***	0.087	0.783	0.000
EPA	0.161	0.048	0.095	0.325	1.007	0.927	273	-3.832***	0.203	0.738	0.000
		Daily conditional volatility, annualized									
Russia	0.088	0.022	0.058	0.168	1.129	0.865	1353	-3.645***	0.042	0.943	0.000
CBoT	0.267	0.042	0.192	0.440	0.807	0.716	1353	-5.111***	0.058	0.908	0.000
EPA	0.166	0.043	0.091	0.322	0.777	0.241	1353	-4.029***	0.076	0.909	0.000

Note: Realized and conditional volatility is the square root of realized and conditional variance, respectively. Weekly and daily volatility series are annualized by multiplying each realization by $\sqrt{52}$ and $\sqrt{260}$, respectively. UR test refers to ADF unit root test. Null hypothesis of ADF test is unit root in series. *** and ** denote statistical significance at the 1 and 5 percent level, respectively. GARCH(1,1) parameters α, β and ω represent the susceptibility to shocks, volatility persistence, and constant term, respectively, with $\alpha + \beta < 1$.

Source: Own calculations

4.5.2 Volatility relations between Black Sea spot and leading futures markets

We estimate a *VAR(3)-X(3)* model, which includes three lags of endogenous, as well as exogenous variables. While the AIC initially favored a *VAR-X* of order one or two, autocorrelation remained present in the model residuals using these specifications. We therefore increase the lag order to three. Using this specification, the asymptotic multivariate Portmanteau test suggests that the model residuals are free from autocorrelation for up to six lags.

The results of our *VAR-X* estimation suggest interdependencies between spot markets in the Black Sea region and major wheat futures markets (Table 9). We find evidence that price volatility at the EPA futures market affects the Black Sea spot market. Precisely, an increase in EPA volatility in one unit corresponds to a rise in spot price volatility of 13.2 percent in the next period. The respective coefficient, $\beta^{rus}_{epa,1}$ is significant at the five percent level of significance. By contrast, CBoT volatility has no significant impact on Russian wheat price volatility, i.e. all $\beta^{rus}_{cbot,i}$ insignificant. Our results suggest that Black Sea spot prices are additionally driven by own lagged volatility at lags one and three. While the respective coefficients, $\beta^{rus}_{rus,1}$ and $\beta^{rus}_{rus,3}$, are significant at the one percent level, $\beta^{rus}_{rus,2}$ shows a negative, statistically insignificant coefficient. We interpret this finding as evidence that price adjustment processes on the considered physical markets are non-continuous and that periods of high activity can be followed by relative calm. This is also in line with anecdotal evidence suggesting repeated "wait-and-see" periods on the physical market, particularly prior to the release of new relevant information (e.g. AgriCensus, 2020). In this respect, Dwyer et al. (2012) further stress that futures price changes do not necessarily lead to price adjustments on physical markets.

The CBoT futures market is affected by price volatility on the Black Sea spot market lagged by one and three periods (Table 9). The autoregressive coefficient representing the first lag ($\beta^{cbot}_{rus,1}$) equals to 0.290

and therefore exhibits the greatest magnitude among all estimated $\beta^{k}_{m,i}$ coefficients. Own lagged values do not drive current CBoT volatility. We further find no evidence of significant responses to EPA volatility. Focusing on the EPA market, our results suggest that it is mainly driven by own lagged RV realizations, with coefficient sizes decreasing from 0.277 at the first, to 0.164 and 0.114 at the second and third lags, respectively. Further, EPA responses to Russian wheat price volatility remain statistically insignificant.

Table 9: Results of VAR-X estimation with signed exchange rate jumps

Endogenous variable (k =)	Russia	CBoT	EPA
Constant (α^k)	0.004** (0.002)	0.018*** (0.004)	0.010*** (0.003)
Russia lag one ($\beta^k_{rus,1}$)	0.192*** (0.065)	0.290** (0.129)	0.086 (0.083)
CBoT lag one ($\beta^k_{cbot,1}$)	0.025 (0.035)	0.075 (0.069)	0.012 (0.044)
EPA lag one ($\beta^k_{epa,1}$)	0.132** (0.054)	0.100 (0.108)	0.277*** (0.069)
Russia lag two ($\beta^k_{rus,2}$)	-0.072 (0.064)	-0.151 (0.128)	0.098 (0.082)
CBoT lag two ($\beta^k_{cbot,2}$)	-0.018 (0.035)	0.095 (0.07)	-0.012 (0.044)
EPA lag two ($\beta^k_{epa,2}$)	-0.009 (0.055)	0.073 (0.11)	0.164** (0.07)
Russia lag three ($\beta^k_{rus,3}$)	0.177*** (0.062)	0.208* (0.125)	-0.084 (0.08)
CBoT lag three ($\beta^k_{cbot,3}$)	0.026 (0.035)	0.101 (0.07)	-0.002 (0.045)
EPA lag three ($\beta^k_{epa,3}$)	0.018 (0.053)	-0.061 (0.107)	0.114* (0.068)
Ruble jump lag one (γ^k_1)	0.138*** (0.048)	0.245*** (0.096)	0.141** (0.061)
Asymmetry lag one (θ^k_1)	0.002* (0.001)	0.001 (0.002)	0.002 (0.001)
Ruble jump lag two (γ^k_2)	-0.158*** (0.049)	-0.028 (0.098)	-0.032 (0.062)
Asymmetry lag two (θ^k_2)	-0.001 (0.001)	0.001 (0.002)	-0.001 (0.001)
Ruble jump lag three (γ^k_3)	0.001 (0.05)	0.063 (0.099)	0.111* (0.063)
Asymmetry lag three (θ^k_3)	0.000 (0.001)	0.000 (0.002)	0.002 (0.001)
Spring (η^k_{spring})	-0.001 (0.001)	0.005** (0.002)	0.001 (0.001)
Summer (η^k_{summer})	-0.001 (0.001)	0.003 (0.003)	0.001 (0.002)
Fall (η^k_{fall})	-0.001 (0.001)	-0.001 (0.002)	-0.001 (0.002)
Shorter week (η^k_{short})	-0.003 (0.002)	0.001 (0.004)	-0.003 (0.002)
Adjusted R^2	0.167	0.150	0.276
Portmanteau χ^2 test statistic	32.882 [0.201]		
Log Likelihood	2719.319		

Note: Estimations based on weekly RV series containing 274 observations. Standard errors in (). P-values in []. Statistical significance at the 1%, 5% and 10% level denoted by ***, **, and *. Null hypothesis of Portmanteau χ^2 test statistic is no autocorrelation. The test refers to no autocorrelation for up to six lags.

Source: Own calculations

Our results provide weak evidence for seasonal patterns in futures price volatility, as the spring and summer indicator variables (η^k_{spring} and η^k_{summer} show positive coefficients against the winter season, which serves as the benchmark. Regarding the CBoT market, results suggest higher volatility in the spring months of April through to June, which are key growing months in the winter wheat production in the Northern Hemisphere. The respective coefficient, η^{cbot}_{spring}, is significant at the five percent level. This finding is in line with Karali and Power (2013) and Karali and Thurman (2010) who similarily report that CBoT wheat price volatility is highest in the spring, followed by the summer. While our results suggest that Black Sea spot market volatility is highest in winter, the effect is not statistically significant at conventional levels. Russian wheat exports typically decrease in January through to March due to insufficient storage capacity, as well as logistical constraints resulting from low temperatures (Heigermoser and Götz, 2019).

4.5.3 Asymmetric responses to ruble exchange rate jumps

Including signed jumps of the ruble exchange rate as exogenous variables in the *VAR* model, we investigate whether wheat price volatility is affected by movements on foreign exchange markets. Adding negative jump indicator variables, we control for asymmetric responses to appreciation versus depreciations (Patton and Sheppard, 2015). Results suggest that all three considered wheat markets are affected by ruble exchange rate movements lagged by one period (Table 9). The respective coefficients γ^{rus}_1 , γ^{cbot}_1, and γ^{epa}_1 equal to 0.138, 0.245 and 0.141, respectively, and are significant at the one, one and five percent level, respectively. A coefficient with a negative sign at the second lag in the Black Sea spot equation (γ^{rus}_2) suggests that periods of strong adjustments to exchange rate jumps are followed by relative calm, which we interpret as additional evidence suggesting discontinuous, stop-and-go activity on physical markets. Market participants likely do not immediately respond to short-term exchange rate fluctuation, but only adjust price offers and bids if the exchange rate movements are assessed to be permanent.

Regarding the two considered futures markets, we find no evidence for asymmetric responses to ruble depreciations and appreciations (coefficients θ_1^{cbot} and θ_1^{epa}). However, focusing on Black Sea spot markets, our results suggest asymmetries at the first lag, as we find θ_1^{rus} to be significant at the ten percent level. This result provides weak evidence that negative jumps (appreciations) have a greater effect on wheat price volatility than positive jumps (depreciations). Therefore, a weakening ruble, which is expected to lead to decreasing USD-denoted wheat export prices, results in a lesser increase in wheat price volatility than a strengthening ruble. The latter would be associated with an increase in USD-denoted export prices. This asymmetric response to ruble appreciations versus depreciations indicates that Russian export prices are more likely to increase in response to a change in the exchange rate, than to decrease. However, while the respective dummy variable is statistically significant, the estimated effect is small in size, which raises questions on the economic significance of this finding.

As a robustness check, we additionally estimated similar *VAR-X* models using simple weekly signed exchange rate returns (see Table A8 in the Appendix).[46] While the weekly return series show a high correlation of 0.92 with the signed jumps, the effect of returns on wheat price volatility is generally smaller in size and less significant. Employing this alternative specification, the effect of ruble exchange rate returns on CBoT volatility (γ_j^{cbot}) is insignificant, while the impact on EPA futures (γ_j^{epa}) is significant at the 10 percent level. We further find all θ_j^k coefficients to be insignificant using this model specification, implying that asymmetric responses to exchange rate movements are not found when signed price returns are used instead of signed jumps. A comparison of log-likelihood

46 Add further estimated a VAR using simple, non-directional weekly realized exchange rate volatility as exogenous driver. Results suggest that lagged exchange rate volatility has no effect on current price volatility on the considered wheat markets.

values suggests that the model employing signed jumps better fits the considered endogenous variable series.

4.6 CONCLUSIONS

The physical wheat trade underwent fundamental changes over the past two decades, as the Black Sea exporters, and particularly Russia, considerably increased their share in global exports. Commodity futures exchanges, such as the CME, the EPA, or the MOEX compete for the establishment of a functioning Black Sea wheat futures contract to reflect the supply and demand situation in the ascendant region. However, compared to traditional futures contracts, the CME's novel BWF contract still shows significantly lower open interest and trading volume.[47] Liquidity, which is a crucial factor determining the effectiveness and thus success of a futures derivatives, typically builds up slowly and the establishment of a trusted, functioning futures markets market can therefore take considerable time (Garcia and Leuthold, 2004). The global wheat futures market landscape can therefore be expected to change slower compared to the physical wheat trade.

To the best of the authors' knowledge, this study is first to analyze interdependencies between Russian spot and CBoT, as well as EPA futures prices. Using a VAR model framework and weekly realized volatility series computed from daily export price indices and proportionally adjusted futures prices, our results suggest that Black Sea wheat markets are driven by EPA, rather than CBoT price volatility. This finding corresponds to the suggestions by Janzen and Adjemian (2017) that the EPA futures market gains in importance for global wheat price discovery because it better reflects the Black Sea region. We further find that price volatility on the Russian wheat export market affects the CBoT futures market. Conversely, the EPA is mostly driven by own lagged values. Regarding

47 In May 2021, the BWF contract showed a daily trading volume of around 1,200 contracts or 60,000 tons on average (CME Group, 2021). This compares to an average of around 100,000 contracts or 13,600,000 tons per day at the CBoT, and 20,000 contracts or 1,000,000 tons per day at the EPA (Kaack, 2021).

a general price leadership relation between spot and futures prices, our results are thus inconclusive as we find bidirectional effects.

Including signed jumps of the ruble exchange rate as exogenous variable to our *VAR* model, our results indicate that movements on the Russian foreign exchange market induce volatility to all three considered wheat markets. These results are congruent with Brümmer et al. (2016a), Jumah and Kunst (2001), as well as Ott (2014). While an effect of the ruble exchange rate on Russian wheat export prices is expected, our finding that ruble jumps result in increasing volatility on EPA and CBoT futures markets indicates that the diversification of the global grain exporter base leads to an increasing number of factors affecting futures markets.

Considering the Black Sea spot market, we additionally find weak evidence of asymmetry, as ruble appreciations lead to a greater increase in wheat price volatility than depreciations. USD-denoted Russian export prices are thus more likely to rise in response to a jump in the ruble exchange rate than they are to decline. A stronger response of futures prices to appreciations is also reported by Karali and Power (2013). The asymmetric response to ruble exchange rate movements is also in line with previous research suggesting that Russian wheat exporters price discriminate between different destination markets by selectively transmitting changes in respective exchange rates to export prices (Uhl et al., 2016, Pall et al., 2013). However, we acknowledge that the size of this asymmetric effect is relatively minor. The question of market power in the Russian grain export sector and the role of the ruble exchange rate in export price formation should be considered in greater detail in future research.

Prices on physical markets, which are characterized by high transaction and entry costs, are staler compared to futures prices. This is reflected in a large share of zero-returns in the daily Russian export price series of 40%, which indicates that the index remains unchanged on two days per week on average. In addition, our calculations further suggest an average annualized volatility of 8% for the Black Sea spot, versus 16% and 25% for the EPA and CBoT futures markets, respectively. These findings are robust to different approaches of estimating volatility, namely the realized estimator *(RV)* and *GARCH*-type approaches. However, a comparison between realized and conditional volatility reveals greater variability (i.e., a higher standard deviation) in the former series. Responding to lower activity and slower adjustment processes on physical markets, we investigate spot-futures relations at a weekly frequency.

We use proportional ratio adjustment techniques to construct continuous futures price series. While these ratio-adjusted futures series are biased in levels, the return series do not exhibit artificial jumps at contract rollover dates. Using this adjustment technique, we can therefore calculate unbiased *RV* measures, which are calculated from price return series.

Our analysis builds on a unique series of daily Russian wheat export price indices, which have not been used in the literature before. This price index is also used as settlement price for the CME's novel BWF swap contract. Swaps can be expected to become increasingly relevant to agricultural futures markets. Compared to traditional, delivery-based derivatives, financially settled swaps circumvent potential physical delivery or receipt of the traded commodity. This is especially advantageous to speculators or funds, which are not active in trading the actual physical commodity. Attracting these types of market participants can enhance a futures market's functionality by providing valuable liquidity (Garcia and Leuthold, 2004). Generally, cash settlement appears advantageous considering Black Sea wheat markets, where physical trade was repeatedly hampered by logistical bottleneck and ad hoc export restrictions in the past. However, export restrictions could still disrupt cash-settled swaps. To exemplify, in case of a complete export ban, an export price assessment woud be impossible as no price quotes would be posted.

The world wheat market undergoes fundamental changes as the Black Sea exporters now account for one third of global exports, while planted wheat area in the USA is at historical lows. Leading futures exchanges started adapting to this situation by introducing new genuine Black Sea wheat futures contracts. However, it takes considerable time to build up sufficient liquidity that required for a fully functional futures market (Garcia and Leuthold, 2004) and the futures market landscape is thus likely to change slower than export shares on the physical wheat market. Further, traditional futures markets will provide a workable solution to Black Sea market participants in the short run. The benefits of highly liquid markets, which allow market participants to quickly move large positions in and out of the market without causing large price responses, might outweigh occasional price divergences. Still, leading exchange already position themselves with novel derivative contracts tailored to the Black Sea market, competing to potentially provide the global wheat price benchmark of the future.

5 WHEAT FUTURES PRICE VOLATILITY AND NEWS ON RUSSIAN EXPORT RESTRICTIONS[48]

48 This research was presented at the 60th Gewisola Annual Meeting in 2020, the IAMO Forum 2020, as well as the economics colloquium of the Martin-Luther-University Halle-Wittenberg in 2021.

In the wake of rapidly rising prices on international markets, grain exporting countries have repeatedly resorted to restricting exports. While such policies are typically intended to dampen domestic food price inflation, they can prompt cascading policy responses by other countries and further exacerbate price surges on world markets. This ultimately jeopardizes food security, particularly in smaller importing countries (Bouët and Laborde, 2016, Mitra and Josling, 2009). During the 2006-08 food price crisis, a total of 33 countries restricted food exports (Sharma, 2011), while Martin and Anderson (2011) estimate that escalating export restrictions explain 30 percent of the observed rise in wheat prices during this food crisis. More recently, 15 countries including Kazakhstan, Russia, and Vietnam restricted food exports amid uncertainty induced by the Covid-19 pandemic (IFPRI, 2021). The imposition of these measures coincided with a steep rise in wheat prices in the second half of March 2020 (see Figure 17) but remained rather short-lived and insignificant in the longer term (OECD, 2020).

This chapter focuses on grain export restrictions introduced by Russia, the world's largest wheat exporter, which has become a key supplier particularly to countries in the MENA region. Alongside other Black Sea exporters such as Kazakhstan and Ukraine, Russia has frequently restricted grain exports in the past. Most notably, the Russian government issued a complete ban on grain exports in August 2010 after droughts and wildfires in key production regions had caused severe harvest shortfalls (Götz et al., 2016a). Further, a wheat export tax was first introduced in December 2014 and repeatedly adjusted in response to expected domestic production and world market price movements (Figure 17). In April 2020, the Russian government introduced a novel quota system aiming to limit grain exports in the months preceding the new harvest. More recently, in late January 2021, Russia imposed a new grain export tax amid concerns regarding rising domestic food prices (Reuters, 2021).

While export restrictions can have a profound impact on food prices, their impact appears difficult to assess for market participants, not least because eventual policy responses by other countries must also be taken into account. It can therefore be hypothesized that news regarding export restrictions (i.e. the risk of policy changes) induces uncertainty and thus price volatility to futures markets, which quickly incorporate new information due to low transaction costs. Against this background, we focus on the following research questions: Does news about Russian grain export restrictions affect wheat futures price volatility? How strong is this effect relative to other types of market events?

Anecdotal evidence suggests that wheat futures markets are frequently affected by rumors regarding Russian export restrictions (Sowell, 2019, AgriCensus, 2018). Van Bommel (2003) shows how market participants informed about a future publication of information can profit from spreading imprecise rumors prior to the news arrival. To gain insights into the potential role of rumors, we additionally evaluate whether price volatility is elevated over a period of seven days before news concerning Russian grain trade policy are published. While pre-announcement effects have rarely been studied thus far (Bauwens et al., 2005), their analysis allows valuable insights regarding the validity of the Efficient Market Hypothesis (EMH)[49] for the considered market. We additionally investigate post-announcement effects over a period of seven days after a news announcement to evaluate whether incoming information is quickly and fully incorporated after news arrival.

Export restrictions are associated with increasing price volatility because their tightening in periods of price rises causes further increases, while their relaxation in periods of decreases adds downward pressure on international prices (Cardwell and Kerr, 2014). Anticyclical export restrictions therefore lead to more extreme prices increasing harm to consumers (producers) in smaller importing (exporting) countries in periods of price rises (declines, Bouët and Laborde, 2016). Complementary to this more long-term understanding of price volatility, we explicitly consider short-term, i.e. intraday volatility effects, which are more closely related to the understanding of volatility as uncertainty.

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49 The EMH states that in an efficient market, the current price already incorporates all available public and private information and price changes must therefore be random and unpredictable (e.g. Malkiel, 2003).

High short-term volatility on futures markets can affect grain markets in multiple ways. It increases the liquidity risk for futures market participants and can lead to company bankruptcies due to more frequent margin calls (Bunek and Janzen, 2015). It affects physical markets by decreasing the availability of forward contracts, as physical traders tend to wait until volatility subsides and new futures prices are discovered (Karali and Power, 2013). Moreover, high volatility increases the demand for physical storage, contributing to higher spot prices (Karali and Ramirez, 2014). High food price volatility further hampers investment in the agricultural sector in general, reducing productivity, quality and availability of food in the long run (Kalkuhl et al., 2016).

To investigate the effect of news arrival on price volatility, we build on high-frequency price data from the CBoT wheat futures market (July 2013 to October 2020). We sample intraday price returns at a standard five-minute frequency to calculate daily realized variance (RV) and jump-robust bipower variation *(BV)* measures for 1,850 CBoT day sessions. For comparison, we further use generalized autoregressive conditional heteroscedasticity *(GARCH)* models and intraday, as well as daily returns to estimate different conditional variance series. This allows a comparison between volatility estimated from intraday versus daily price data.

Using the Barndorff-Nielsen and Shephard (BNS, 2006) test for the presence of jumps in high-frequency price series, we initially investigate the occurrence and magnitude of price jumps for the event types considered. We subsequently estimate seasonally adjusted autoregressive moving average *(ARMA)* models that include sequences of news indicator variables as exogenous drivers *(ARMA-X)*. Following this approach, the news impact on, before, and after news arrival days can be quantified independently. The Russian trade policy news indicator variable comprises 89 newswire reports published by news agency Interfax, which closely reports on Russian grain trade policy. The volatility effect of Russian trade policy news is compared with releases of World Agricultural Supply and Demand Estimates (WASDE) reports published by the USDA (Adjemian and Irwin, 2018, Karali et al., 2019, Isengildina-Massa et al., 2008) as well as tender openings by the GASC, Egypt's food procurement agency.

This chapter is organized as follows: The next section provides a review of relevant literature. Our dataset is described in section 5.2, while the methodology is presented in the subsequent section. The construction of the event indicator variables is described in detail in section 5.4. Our results are presented in section 5.5. Finally, we provide conclusions in the final section.

5.1 LITERATURE REVIEW

The effect of grain trade policy announcements on short-term futures price volatility has not been studied in the literature thus far. However, several studies have investigated the impact of Black Sea grain export restrictions on domestic physical markets. Employing a price transmission framework, Götz et al. (2013b) find that Ukrainian export quotas and Russian export taxes introduced during the 2007/08 food crisis lead to increased instability on domestic markets as they became disconnected from world market prices. Using a smooth transition cointegration approach, Götz et al. (2016b) further find that market participants in Ukraine adjust their behavior in anticipation of future export restrictions. Focusing on the effects of export restrictions on vertical wheat-to-flour price transmission in Ukraine, An et al. (2016) similarly observe increased volatility in the flour market immediately preceding trade restrictions. Conducting a simulation study, Fellmann et al. (2014) suggest that export restrictions by Black Sea exporters incresase international wheat prices, with adverse effects for food security in net importing countries. Rude and An (2015) further use monthly grains and oilseed prices (1994 and 2010) to measure the effect of export restrictions on volatility computed as a moving standard deviation. They find that wheat market volatility was especially affected by trade restrictions between 2006 and 2010.

Our methodological approach follows several studies that analyze the linkage between news arrivals and realized volatility using event indicator variables. Focusing on the effect of central bank intervention on foreign exchange markets, Beine et al. (2007) estimate autoregressive fractionally intergrated moving average *(ARFIMA)* models with daily realized volatility as dependent variable and intervention dummies to quantify the effect of policy shocks to exchange rate volatility. Similar approaches are employed by Cheng et al. (2013) and Lyocsa et al. (2019) who analyze how stock market realized volatility responds to central bank announcements. Chan and Gray (2018) investigate macroeconomic news announcements, comparing their effect on realized versus implied volatility. They find that realized volatility increases on the considered news days, while implied volatility, which can be derived from options prices, decreases.

Aside from indicator-variable approaches, the effect of news arrival on asset price volatility is also investigated using news count variables (see Chang and Taylor, 2002, Plante, 2019, Janssen, 2004). A drawback of this approach is that pre- or post-announcement effects cannot be examined. As anecdotal evidence suggests that changes in Russian grain trade policy are frequently accompanied by periods of rumors and speculation thereof, we employ an indicator-variable approach that allows us to independently assess pre-announcement effects, which are rarely considered in previous research (Bauwens et al., 2005, Bomfim, 2003).

We compare the volatility effects of Russian grain trade policy news with market responses to releases of WASDE reports, which have been thoroughly studied in the literature. Focusing on CBoT maize and soybean markets, Isengildina-Massa et al. (2008) find that WASDE publications are associated with significantly larger close-to-open returns in the time period 1985 to 2005, when USDA reports were published before the start of the CBoT day session. Pre- or post-announcement effects five days before or after report releases were not determined. This in line with Bunek and Janzen (2015) who investigate the effect of USDA report publications on realized volatility on the KCBoT futures market, finding significant announcement effects only on publications days. Further analyzing WASDE effects using intraday price data, Adjemian and Irwin (2018) find that the transition to publishing USDA reports during CBoT trading sessions resulted in a considerable increase in volatility on release days. However, this hightened volatility persists only for a short period and subsides within few trading minutes. This finding is in line with Lehecka et al. (2014) who confirm that the CBoT corn market incorporates new public information within around ten minutes. In a more recent study, Karali et al. (2019) investigate how differences in analyst estimates and actually published WASDE statistics (i.e. market 'surprises') affect the size of the announcement effect observed on the day of publication.

5.2 DESCRIPTION OF USED HIGH-FREQUENCY PRICE DATASET

This analysis employs transaction-specific price data from the CBoT soft red winter (SRW) wheat futures market. Prices are recorded at millisecond-precision and are obtained from Tick Data (2020). We consider the CBoT because of its high liquidity and leading role in price discovery versus other wheat futures markets (Janzen and Adejmian, 2017). Our period of investigation ranges from July 1, 2013 through to October 30, 2020, comprising 1,850 trading days and 24,007,906 single transactions. We consider CBoT day sessions, which start at 8:30 a.m. CST and end at 1:20 p.m. CST[50] and show greater trading volume compared to night sessions. The analysis focuses on the nearest, i.e. front month contracts, which are typically most actively traded. To concatenate series representing individual contracts into one continuous futures series, we switch from nearest to second-nearest contracts one month prior to expiry of the former. As front-month contracts tend to lose liquidity in the weeks directly preceding contract expiry when positions are closed or moved to deferred contracts, a contract-transition one month prior to expiry represents a standard approach in the literature (Vollmer et al., 2020, see also section 4.3). Within our sample, the CBoT day session finishes early on 22 days due to subsequent US holidays, which we control for in the regression analysis. Further, we account for two limit-up days occurring on July 3, 2017, and

50 Before July 3, 2015, the CBoT day session closed five minutes earlier at 1:15 pm CST.

July 25, 2018, when trading was halted for 29 and 17 minutes, respectively, due to price increases exceeding 35 cents per bushel versus the last closing price.

5.3 METHODOLOGY: THE ARMA-X APPROACH

Our empirical analysis builds on the concept of RV (see equation (2)), which is calculated from intraday, high-frequency price returns in this chapter. Based on the theory of quadratic variation, the daily RV of a financial asset is computed as the sum of evenly sampled squared intraday price returns (Barndorff-Nielsen and Shepard, 2002, Andersen et al., 2003, McAleer and Medeiros, 2008). Using the RV estimator specified in section 4.4, we construct an intraday price series employing calendar-time-sampling at a standard five-minute frequency, selecting the last price observation within each five-minute time interval as respective price observation (Liu et al., 2015, Thomakos and Wang, 2003, Ghysels et al., 2006). As the CBoT day session lasts for 290 minutes, a five-minute frequency implies 57 intraday returns. However, to avoid disregarding the first five-minute interval, an additional return is calculated as relative change between the opening price and the last price in the first five-minute interval.[51] To deal with microstructure noise, we use $MA(1)$ models to 'filter' the intraday return series (Thomakos and Wang, 2003).[52]

The 'naïve' RV calculated from equation (2) cannot distinguish between the continuous (or permanent) component of volatility, and the transitory component reflecting a jump in the price level (Andersen et al., 2003, Beine et al., 2007). As price jumps do not correspond to the common understanding of volatility as uncertainty or 'price swings',

51 We thus focus on open-market-volatility, as we do not consider overnight, close-to-open returns.

52 The average MA(1) term equals -0.064 using a five-minute frequency, becoming larger in absolute size at increasing sampling frequencies. At a ten-second frequency, it averages at -0.150 and is significant at the 5% level.

Barndorff-Nielsen and Shephard (2004) propose the estimation of realized bipower variation (BV), which allows to disentangle the two components by consistently estimating the continuous component in the presence of jumps. BV, defined as the sum of the product of adjacent absolute intraday returns standardized by a constant, can be written as:

$$BV_t = \mu_1^{-2} \sum_{j=2}^{N} |r_j|\,|r_{j-1}| \tag{7}$$

with $\mu_1 = \sqrt{2/\pi} \approx 0.79788$ being the mean of the absolute value of a standard normally distributed random variable. After calculating RV_t and BV_t, the jump component, J_t, can be derived by $RV_t - BV_t = J_t$. However, to avoid the consideration of statistically and economically insignificant jumps, we employ the Barndorff-Nielsen and Shephard (BNS, 2006) test for the presence of jumps in high-frequency price series. Its basic intuition is to test whether the difference between RV_t and BV_t is statistically significant, based on a pre-defined level of confidence ($\alpha = 0.975$ in our case).[53] If the test's null hypothesis of no jumps is not rejected, the (insignificant) jump will be considered as part of the continuous component and not as discontinuity in the price process (Beine et al., 2007, Chevallier and Sevi, 2012). In this instance, $BV_t = RV_t$ and $J_t = 0$, while $BV_t < RV_t$ and $J_t > 0$ if a significant jump is detected on day t. Based on results of the BNS test, we initially report statistics on the occurrence and magnitude of detected jumps over the whole sample period, as well as within subsamples representing the considered event types (Beine et al., 2007)

As a comparison, we further estimate conditional variance using standard $GARCH(1,1)$ models laid out in equation (3) (see section 4.4). As the dataset used in this chapter is based on intraday price data, we estimate CV_t from daily (CV_t^d), as well as intraday (CV_t^i) return series. Regarding CV_t^i, we ensure comparability with the daily RV_t and BV_t series by computing the average intraday conditional variance ($\overline{CV}_t^i$) for each trading day. A drawback of volatility estimation using parametric $GARCH$ models is

53 Please see Beine et al., 2007, Chevallier and Sevi, 2012, Huang and Tauchen, 2005, and Andersen et al., 2017, for detailed descriptions of the jump detection test.

possible convergence failures. Further, the estimation using maximum likelihood requires the assumption of a return distribution, which is often arbitrary (Stigler, 2011). Both issues do not occur computing model-free *RV*.

Following Bauwens et al. (2005), Lyocsa et al. (2019) and Bomfim (2003), we investigate volatility effects on, before and after days, when news events occur. Precisely, contemporaneous, pre- and post-announcement volatility effects of three different news types are estimated by including sequences of indicator variables into a seasonally adjusted *ARMA-X* model, which can be written as:

$$BV_t = \alpha_0 + \sum_{i=1}^{p} \beta_i BV_{t-1} + \sum_{j=1}^{q} \gamma_j \varepsilon_{t-j} + \sum_{l=-L}^{L} \delta_l^k news_{t-l}^k + \theta^s season_t^s + \varepsilon_t \quad (8)$$

where BV_t denotes the logarithm of jump-robust bipower variation on day t, with $t = 1, 2, \dots, T$. α_0 represents a constant term. $news_{t-l}^k$ is an indicator variable that equals one if news regarding event type k is released in period $t - l$, and zero otherwise. δ_l^k therefore denotes the volatility effect of event type k, at period $t - l$, with $l = -7, -6, \dots, 0, \dots, 6, 7$, as $L = 7$. For each event type k, we thus assess the contemporaneous effect δ_{t+0}^k, as well as pre- and post-announcement effects for seven separate days before and after the news event. The three news types considered are Russian grain trade policy news, WASDE publications and GASC tender openings, i.e. $k = \{russia, wasde, gasc\}$. We account for seasonality in volatility (Karali and Power, 2013, Simon, 2002, Karali and Thurman, 2010), day-of-the-week effects and long-term trends (Martens et al., 2009, Bomfim, 2003, Areal and Taylor, 2002), by including $season_t^s$, a set s dummy variables, which equal to one if observation BV_t refers to the respective month, year or weekday, respectively, and zero, otherwise. θ^s thus represents the effect of seasonal component s. We further include three control dummy variables representing CBoT limit days, sessions with shorter trading hours and a change in CBoT opening hours occurring on July 3, 2015, respectively. To ensure that model residuals are serially uncorrelated, p autoregressive *(AR)* and q moving average *(MA)* terms are added to the model, with β_i and γ_j representing *AR* and *MA* parameters at the i^{th} and j^{th} lag, respectively. Finally, ε_t is a vector of independent and identically distributed error terms.

While the interpretation of lag indicator variables (i.e. δ_l^k, with $l = 1, 2, \dots, 6, 7$) assesses the persistence of a volatility effect induced by a news shock, the lead indicator variables (i.e. δ_l^k, with $l = -7, -6, \dots, -2, -1$) indicate whether volatility at period t is affected by anticipation of a future event. This specification is advantageous if pre-scheduled or otherwise expected events are investigated. In this case, altered volatility in pre-announcement periods appears plausible, as market participants anticipate new information and potentially adjust positions. The inclusion of lead dummy variables further allows us to draw meaningful conclusions regarding the validity of the EMH. Precisely, a significant pre-announcement effect can be interpreted as resulting from 'private' information being incorporated into the price before it becomes 'public', i.e. when $news_{t-0}^k = 1$.

With $p = 1$, $q = 1$, $k = 3$, $L = 7$ and $s = 25$, the full model contains 72 parameters. While we define the jump-robust BV_t as benchmark dependent variable, we additionally estimate the identical model specification using RV_t, $\overline{CV}_t^i$, as well as CV_t^d for comparison.

5.4 CONSTRUCTION AND DESCRIPTION OF EVENT INDICATOR VARIABLE

The volatility effect of news concerning Russian grain trade policy is assessed using an event indicator variable, which equals one on days when respective news are published and zero otherwise. Volatility effects are compared with two further types of news, namely WASDE reports published by the USDA and openings of wheat tenders by the GASC, the Egyptian state procurement agency for food commodities, which is one of the largest single wheat buyers on the international market.

The Russian grain trade policy indicator variable is constructed based on the Russia & CIS Business and Financial Newswire. This service is provided by the news agency Interfax, which closely reports on the Russian grain sector. Using the Nexis Uni Database (Nexis Uni, 2020), we extract all news items from this newswire that mention at least one word from each of the following four lists in headline or lead paragraph:

1. 'Russia' or 'Moscow' or a state agency or politician responsible for grain trade policy[54]
2. 'wheat', 'grain' or 'cereal'
3. 'export' or 'trade'
4. 'restriction', 'tax', 'quota', 'control', 'duty', 'tariff', 'ban', 'limit', 'curb', or 'regulation'

Following this procedure, we obtain a total of 260 news items published between July 1, 2013, and October 30, 2020. We subsequently exclude reports that focus on trade restrictions directed at individual countries, are imposed on Russia,[55] speculate about effects of export restrictions, or notify that previously announced policies have taken effect. This leaves 96 news items. As seven reports are published during weekends or on US holidays, a total of 89 items are considered in our analysis.

Figure 17 presents each occurring news event, singling out specific policy decisions, while Table A9 in the annex lists date and headline of each news item. Figure 17 shows that on December 22, 2014, the Russian government announced the introduction of export duties to stabilize domestic grain markets. The tax took effect on February 1, 2015, amounting to 15 percent of the customs value plus 7.5 euro, but at least 35 euro per ton. This decision followed several denials of such policy change in preceding weeks, which is the case regarding several policy decisions

54 Further search terms include Russian ministers of agriculture, (deputy) prime ministers, or presidents, 'Dvorkovich', 'Tkachev', 'Patrushev', 'Gordeyev', 'Belousov', 'Medvedev', 'Putin', the name of the federal agency for veterinary and phytosanitary surveillance, 'Rosselkhoznadzor', as well as 'Moscow'.

55 Most notably, reports on restrictions of grain trade with Turkey in 2017 are not included.

throughout the sample (see Table A9). We explicitly include denials of export restrictions in this analysis, because they can suggest that such policy changes are at least considered.

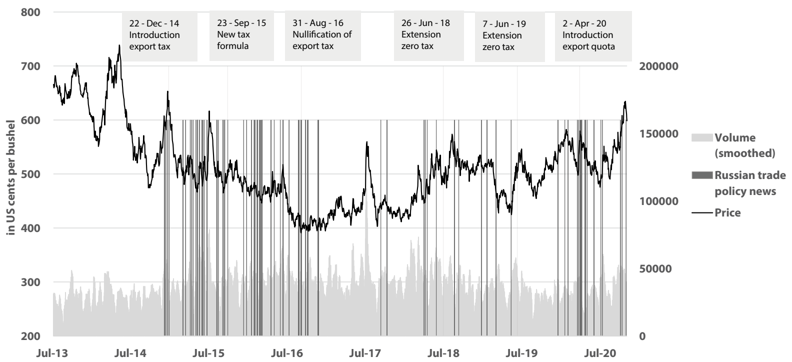

Figure 17: CBoT closing prices, trading volume and selected Russian trade policies

Note: Vertical lines represent Russian grain trade restriction news published by Interfax news agency. For better visibility, trade volume is smoothed and presented as a three-day moving average.

Source: Own illustration based on Nexis Uni (2020) and Tick Data (2020)

The cancellation of the export tax communicated on May 15, 2015 was only short-term. Already two weeks later, it was reported that from July 1, 2015, '[t]he rate of the duty will be 50% minus 5,500 rubles per tonne, but no less than 50 rubles per tonne.' The formula to calculate the tax was again adjusted on September 23, 2015 (Figure 17). Specifically, the tax deductible was increased from 5,500 to 6,500 rubles per ton and the minimum duty was lowered from 50 to 10 rubles per ton starting on October 1, 2015. After extensive discussions about policy adjustments throughout 2016, the nullification was finally announced on August 31, to ultimately take effect on September 23, 2016. In view of continuously increasing wheat production, decisions to prolong the zero-tax regime were announced on June 26, 2018, and June 7, 2019.

Amid high uncertainty induced by the ramifications of the Covid-19 pandemic, the Russian federal agency for veterinary and phytosanitary surveillance (Rosselkhoznadzor) introduced a ten-day ban on cereal exports starting March 20, 2020, which was lifted early on March 24. Shortly after, a quota limiting grain exports between April and June 2020 to 7 million tons was adapted (Figure 17).[56] The Russian Agricultural Ministry had first announced this new 'mechanism to curb grain exports' on January 29, 2020, stating that an export quota would subsequently be set for every future farming year. Starting in late September 2020, reports suggested that the Russian Agricultural Ministry was indeed considering new quotas between January and June 2021 to 'stabilize prices on [the] Russian market.'

For comparison, we construct a second event indicator variable representing releases of WASDE reports by the USDA (2021). WASDE reports are published monthly and provide country-specific projections of grain production, exports and ending stocks, inter alia. These statistics are referred to as the 'gold standard' of global supply and demand estimation (Reuters, 2019d) and are thus widely anticipated. Our period of investigation comprises 86 WASDE release days (Figure A6). Since May 2012, WASDE reports are published during CBoT day sessions at 11:00 a.m. CST (Adjemian and Irwin, 2018). Prior to a report release, private analysts' estimates of the provided statistics are polled, summarized and published by Reuters (Karali et al., 2019). The CBoT futures market is found to react strongly to information contained in WASDE reports, processing the news estimates in only a few trading minutes (Adjemian and Irwin, 2018).

Openings of GASC wheat tenders constitute the third event indicator variable under consideration (Zerno Online, 2020). The GASC is the state procurement agency for food commodities of Egypt, the world's largest wheat importer. The GASC manages around half of Egypt's imports, buying as much wheat as the whole of Japan (Heigermoser et al., 2021). Numerous trading companies regularly compete in GASC tenders, which are issued roughly every two weeks. Our sample period comprises 181 tender openings (Figure A7). GASC tender results are widely reported

56 As Russian grain exports typically decrease considerably in the winter and spring months (Heigermoser and Götz, 2019), this quota was barely prohibitive.

and discussed in the grain industry, as they provide up-to-date import price information from a highly competitive, central physical market close to the Suez Canal. However, in contrast to Russian grain trade policy news and WASDE publications, GASC tenders do not reveal information on (export) supply or demand, but provide current prices on physical markets. While GASC tenders are not scheduled and the exact timing of openings is unpredictable, it can still be expected that a tender opening will not surprise market participants as the agency's overall demand is largely predictable.

5.5 ESTIMATION RESULTS

5.5.1 Characteristics of CBoT wheat futures price volatility

Figure 18 presents the computed realized volatility[57] series, its separate jump and continuous components, as well as conditional volatility series estimated using *GARCH(1,1)* models. For better comparability, we present all volatility series in annualized form.[58] The realized volatility and the continuous component (jump-robust bipower variation) show signs of clustering, which is a common feature of asset price volatility. Autocorrelation functions of both series confirm slowly decaying autocorrelation over the first 60 lags, with a coefficient below 0.4 at the first lag. This finding is in line with Thomakos and Wang (2003) and motivates us to subsequently estimate *ARMA* models to deal with serial correlation.[59] Conversely, the transitory (jump) component does not exhibit

57 Realized and conditional volatility is defined as the square root of realized and conditional variance, respectively.

58 To annualize, the series are multiplied by the square root to the number of business days within one year, i.e. 252.

59 This autocorrelation structure serves as some indication for the use of autoregressive fractionally integrated moving average (ARFIMA) models. We therefore estimated ARFIMA models as a robustness check and received qualitatively similar results regarding the effect of our event variables.

serial autocorrelation, which is in line with an efficient market where changes in the price level cannot be predicted from past price changes. Figure 18 further suggests seasonal patterns in all presented volatility series. Wheat price volatility appears higher in May through to August, i.e. during US growing and harvesting periods, while volatility is lower during winter months. This observation serves as further indication for the inclusion of monthly dummy variables in the following analysis.

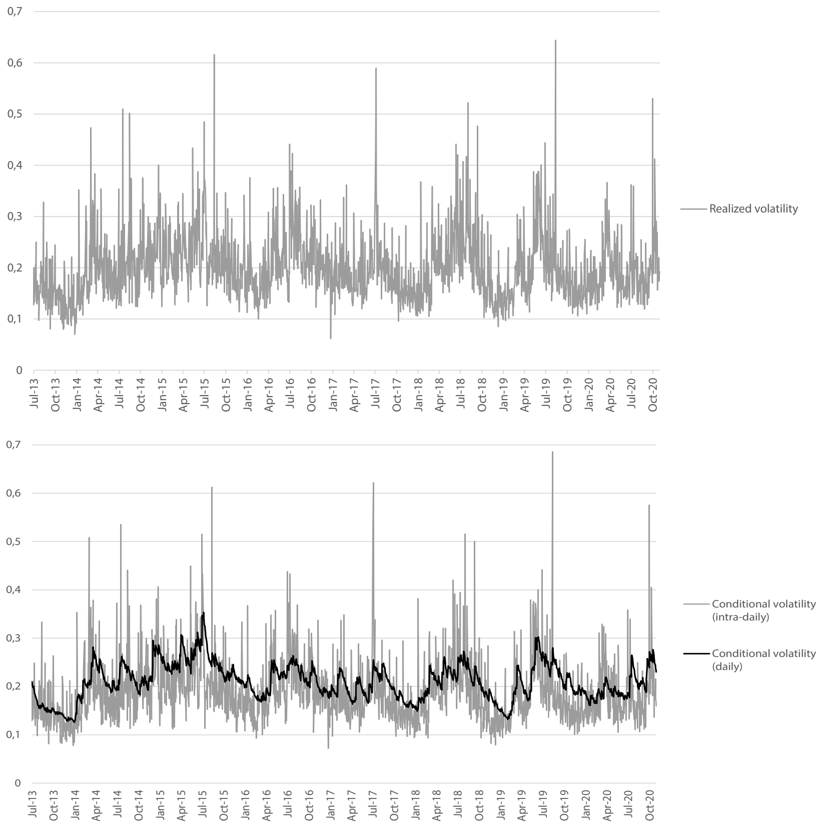

Figure 18: Realized and conditional volatilities, continuous and jump components

Note: The continuous and jump components are defined based on BND jump tests with α=0.975.

Source: Own calculations

to be continued

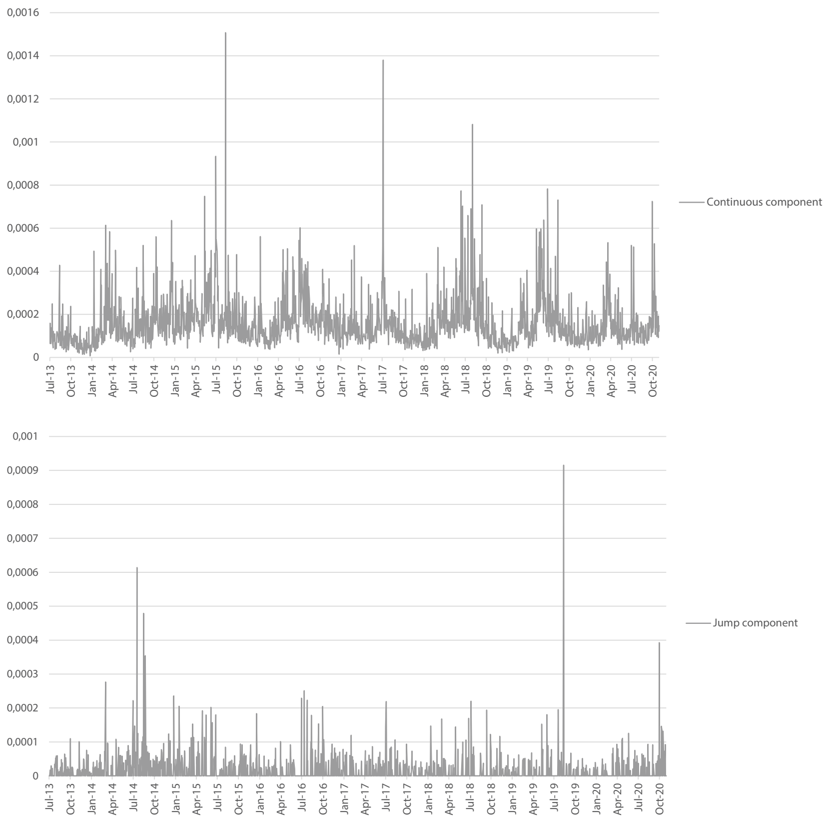

Figure 18: Realized and conditional volatilities, continuous and jump components (continued)

Note: The continuous and jump components are defined based on BND jump tests with α=0.975.

Source: Own calculations

Figure 18 further presents two annualized conditional volatlity series estimated using $GARCH(1,1)$ models. The first presents the average conditional volatlity ($\overline{CV}_t^i$) estimated from intraday price returns sampled at at five-minute frequency, i.e. same intraday returns underlying the realized volatility series. Notable differences between the $\overline{CV}_t^i$ and RV_t, as well as BV_t are not apparent. However, the conditional volatility series estimated from daily returns (CV_t^d), clearly appears 'compressed', exhibiting smaller maxima and greater minima. However, the two conditional volatility series follow the same overall trend, reaching local maxima and minima in similar periods.

The descriptive statistics presented in Table 10 confirm these observations. Conditional volatility estimated from daily returns has a smaller standard deviation than volatility series computed from intraday data. Table 10 further suggests that the three volatility series presented in annualized form exhibit similar mean values, ranging between 19% and 21%. Further, logarithmic transformations of the considered volatility series result in skewness and kurtosis values approaching zero and three, respectively, and thus normality. This finding is in line with Lyocsa et al. (2019).

Table 10: Descriptive statistics of considered daily volatility measures:

	Minimum	Mean	Maximum	Standard Deviation	Skewness	Kurtosis
Realized volatility p.a. (RV_t)	0.062	0.201	0.644	0.065	1.484	7.446
Mean conditional intraday volatility p.a. ($\overline{CV}_t^i$)	0.072	0.190	0.686	0.065	1.824	9.550
Conditional daily volatility p.a. (CV_t^d)	0.126	0.210	0.353	0.038	0.234	2.97
Log of BV_t	-11.806	-8.945	-6.498	0.629	0.054	3.527
Log of RV_t	-11.097	-8.831	-6.410	0.601	0.243	3.434
Log of $\overline{CV}_t^i$	-10.830	-8.982	-6.284	0.623	0.445	3.558
Log of CV_t^d	-9.674	-8.684	-7.610	0.364	-0.251	2.808

Note: Realized and conditional volatility is the square root of realized and conditional variances, respectively. If denoted p.a. ('per annum'), the series are annualized by multiplying each value by the square root of 252 (number of business days in one year). The mean conditional volatility estimated from five-minute intraday returns is annualized by $\sqrt{252 * 57}$, as there are 57 five-minute returns during the CBoT day session.

Source: Own calculations

5.5.2 VOLATILITY EFFECTS OF RUSSIAN GRAIN TRADE POLICY ANNOUNCEMENTS

Following Beine et al. (2007), we first present statsitics on the occurrence of jumps in the RV_t series (Table 11). The Barndorff-Nielsen jump test $(\alpha = 0.975)$ suggests that significant jumps occur during 559 of the considered trading days (30.2%). Regarding the remaining 1291 trading days, jumps are found to be insignificant, implying that $RV = BV$ on 69.8% of days. Jumps are less frequent (20.2%) when Russian grain trade policy news are reported but are 24% greater than average if they occur (0.149 versus 0.120 in the full sample). Significant jumps are detected on 34 out of 86 WASDE release days (39.5%). Jumps thus occur more frequently on WASDE publication days and are also 44% larger (0.173 versus 0.120) compared to the total sample. Regarding GASC tender opening days, no notable differences in jump occurrence or intensity can be determined.

Table 11: Occurrence of significant jumps

	Total sample	Russian grain trade policy news	WASDE report releases	GASC tender openings
Observations	1850	89	86	181
Jump occurrence	559	18	34	54
Jump proportion	30.2%	20.2%	39.5%	29.8%
Average J975	0.066	0.067	0.109	0.062
Average J975>0	0.120	0.149	0.173	0.113

Note: Average J975 represents the average jump including days where the jump equals zero. Average J975 > 0 represents only the subsample of significant jumps.

Source: Own calculations

Table 12 presents results of our *ARMA-X* model estimations. Results of our benchmark model suggest that Russian grain trade policy news increase wheat futures price volatility by 18.6% on the day of publication (δ_0^{russia}). This effect is statistically significant at the one percent level. We further find evidence for significant pre-announcement effects, which are also visually presented in Figure 19. Wheat price volatility is elevated on several days preceding the release of news regarding Russian grain trade policy. This effect is significant at the five percent level two, three and five days prior to a news event. This finding suggests that information contained in the news reports is (partly) incorporated into market prices prior to their publication at $t + 0$. A possible explanation is that market participants anticipate the respective policy news, or get access to information before it is published by Interfax. This finding is also in line with anecdotal evidence suggesting that rumors about possible trade restrictions induce volatility to wheat markets (Sowell, 2019, AgriCensus, 2018). Regarding the post-announcement period, we find no significant volatility effects. This suggests that the considered policy news are efficiently processed and new market prices are rapidly discovered.

Table 12: Results of ARMA-X model estimations

	δ_l^k	Bipower variation (BV)	Realized variance (RV)	Mean Conditional variance intraday returns ($\overline{CV_i}$)	Conditional variance daily returns (CV_d)
	l =	**Russian grain trade policy news (*k = russia*)**			
Days prior to event (δ_l^{russia})	7	0.049 (0.052)	0.042 (0.049)	0.017 (0.052)	-0.013 (0.007)
	6	-0.005 (0.053)	0.035 (0.05)	0.022 (0.052)	0.011 (0.010)
	5	0.112** (0.053)	0.101** (0.051)	0.113** (0.053)	0.015 (0.012)
	4	0.042 (0.053)	0.013 (0.051)	0.003 (0.053)	0.015 (0.013)
	3	0.132** (0.053)	0.128** (0.051)	0.160*** (0.053)	0.007 (0.014)
	2	0.114** (0.054)	0.123** (0.052)	0.098 (0.054)	0.015 (0.015)
	1	0.075 (0.054)	0.073 (0.052)	0.082 (0.054)	0.012 (0.015)
Event (δ_0^{russia})	0	0.186*** (0.054)	0.150*** (0.052)	0.159*** (0.054)	0.016 (0.015)
Days after event (δ_l^{russia})	-1	0.039 (0.054)	0.050 (0.052)	0.040 (0.054)	-0.004 (0.015)
	-2	0.077 (0.054)	0.073 (0.052)	0.084 (0.054)	-0.010 (0.015)
	-3	0.063 (0.054)	0.053 (0.051)	0.077 (0.054)	-0.013 (0.014)
	-4	0.003 (0.054)	0.002 (0.051)	0.028 (0.053)	-0.015 (0.013)
	-5	0.024 (0.053)	0.014 (0.051)	0.011 (0.053)	-0.014 (0.012)
	-6	0.034 (0.053)	0.029 (0.05)	0.032 (0.053)	-0.004 (0.010)
	-7	0.000 (0.052)	0.012 (0.05)	0.011 (0.052)	-0.006 (0.007)
		WASDE releases (*k = wasde*)			
Days prior to event (δ_l^{wasde})	7	0.246*** (0.052)	0.234*** (0.049)	0.307*** (0.052)	0.007 (0.007)
	6	0.134** (0.053)	0.121** (0.051)	0.146*** (0.053)	0.029*** (0.01)
	5	0.237*** (0.054)	0.228*** (0.051)	0.206*** (0.054)	0.024** (0.012)
	4	0.122** (0.054)	0.127** (0.052)	0.113** (0.055)	0.026** (0.013)
	3	0.027 (0.055)	0.000 (0.053)	-0.017 (0.055)	0.017 (0.014)
	2	-0.079 (0.055)	-0.064 (0.053)	-0.049 (0.056)	0.012 (0.014)
	1	0.019 (0.055)	0.011 (0.053)	0.003 (0.056)	0.006 (0.015)
Event (δ_0^{wasde})	0	0.808*** (0.055)	0.825*** (0.053)	0.944*** (0.056)	-0.005 (0.015)
Days after event (δ_l^{wasde})	-1	0.051 (0.055)	0.033 (0.053)	0.046 (0.056)	0.023 (0.014)
	-2	0.080 (0.055)	0.039 (0.053)	0.047 (0.055)	0.025 (0.014)
	-3	0.141** (0.054)	0.123** (0.052)	0.115** (0.055)	0.024 (0.013)
	-4	0.098 (0.054)	0.073 (0.052)	0.065 (0.054)	0.014 (0.013)
	-5	0.060 (0.053)	0.070 (0.051)	0.078 (0.054)	0.015 (0.011)
	-6	0.056 (0.052)	0.028 (0.05)	0.052 (0.052)	0.001 (0.010)
	-7	0.061 (0.051)	0.062 (0.049)	0.060 (0.051)	0.007 (0.007)
		GASC tender openings (*k = gasc*)			
Days prior to event (δ_l^{gasc})	7	-0.04 (0.037)	-0.021 (0.036)	-0.016 (0.037)	-0.002 (0.005)
	6	-0.009 (0.039)	-0.026 (0.038)	-0.022 (0.039)	-0.012 (0.008)
	5	-0.041 (0.041)	-0.036 (0.039)	-0.04 (0.041)	-0.011 (0.009)
	4	0.000 (0.042)	-0.009 (0.04)	-0.009 (0.043)	-0.012 (0.011)
	3	0.025 (0.043)	0.023 (0.041)	0.023 (0.043)	-0.014 (0.012)
	2	-0.03 (0.043)	-0.037 (0.041)	-0.021 (0.043)	-0.018 (0.013)
	1	-0.045 (0.043)	-0.047 (0.042)	-0.072 (0.044)	-0.007 (0.013)
Event (δ_0^{gasc})	0	-0.059 (0.043)	-0.061 (0.041)	-0.063 (0.044)	-0.008 (0.013)
Days after event (δ_l^{gasc})	-1	-0.067 (0.043)	-0.074 (0.042)	-0.081 (0.044)	-0.016 (0.013)
	-2	-0.046 (0.043)	-0.064 (0.041)	-0.051 (0.043)	-0.021 (0.013)
	-3	-0.001 (0.042)	-0.027 (0.041)	-0.038 (0.043)	-0.022 (0.012)
	-4	-0.042 (0.042)	-0.051 (0.04)	-0.042 (0.042)	-0.013 (0.011)
	-5	-0.068 (0.041)	-0.05 (0.039)	-0.053 (0.041)	-0.016 (0.009)
	-6	-0.053 (0.039)	-0.021 (0.037)	-0.029 (0.039)	-0.011 (0.008)
	-7	0.058 (0.037)	0.032 (0.036)	0.027 (0.037)	-0.006 (0.005)

to be continued

Table 12: Results of ARMA-X model estimations (continued)

	Bipower variation (BV)	Realized variance (RV)	Mean Conditional variance intraday returns (CV_i)	Conditional variance daily returns (CV_d)
AR(1)	0.926*** (0.017)	0.917*** (0.019)	0.910*** (0.021)	0.981*** (0.005)
MA(1)	-0.736*** (0.03)	-0.724*** (0.034)	-0.711*** (0.036)	0.016 (0.025)
Constant	-9.887*** (0.177)	-9.666*** (0.162)	-8.954*** (0.166)	-8.845*** (0.171)
Tuesday	0.006 (0.032)	-0.007 (0.031)	-0.021 (0.032)	0.004 (0.003)
Wednesday	-0.011 (0.033)	-0.033 (0.031)	-0.033 (0.032)	0.003 (0.004)
Thursday	0.079** (0.033)	0.062** (0.031)	0.063 (0.033)	0.002 (0.004)
Friday	-0.018 (0.033)	-0.006 (0.031)	-0.006 (0.032)	0.006 (0.003)
February	0.196** (0.097)	0.121 (0.092)	0.116 (0.096)	0.046 (0.024)
March	0.450*** (0.115)	0.350*** (0.108)	0.360*** (0.113)	0.106*** (0.033)
April	0.184 (0.123)	0.140 (0.115)	0.152 (0.119)	0.114*** (0.038)
May	0.341*** (0.127)	0.304*** (0.118)	0.285** (0.121)	0.115*** (0.042)
June	0.405*** (0.128)	0.418*** (0.118)	0.448*** (0.121)	0.091*** (0.045)
July	0.529*** (0.128)	0.505*** (0.119)	0.482*** (0.122)	0.124*** (0.047)
August	0.455*** (0.125)	0.415*** (0.116)	0.395*** (0.119)	0.081 (0.047)
September	0.292** (0.126)	0.275** (0.117)	0.265** (0.120)	0.054 (0.047)
October	0.137 (0.124)	0.095 (0.116)	0.068 (0.120)	0.03 (0.045)
November	-0.028 (0.122)	-0.043 (0.114)	-0.063 (0.118)	-0.003 (0.043)
December	-0.109 (0.105)	-0.106 (0.100)	-0.130 (0.104)	0.063 (0.04)
2014	0.656*** (0.16)	0.641*** (0.146)	0.572*** (0.149)	0.095 (0.075)
2015	0.909*** (0.198)	0.887*** (0.18)	0.801*** (0.184)	0.118 (0.113)
2016	1.025*** (0.253)	0.956*** (0.232)	0.850*** (0.237)	0.094 (0.141)
2017	0.850*** (0.258)	0.755*** (0.235)	0.680*** (0.239)	0.099 (0.165)
2018	0.941*** (0.257)	0.878*** (0.234)	0.765*** (0.239)	0.117 (0.189)
2019	0.926*** (0.258)	0.846*** (0.235)	0.749*** (0.239)	0.165 (0.215)
2020	0.819*** (0.27)	0.759*** (0.246)	0.645*** (0.250)	0.164 (0.248)
Shorter session	-0.372*** (0.1)	-0.266*** (0.096)	0.105 (0.100)	0.002 (0.011)
Limit days	0.389 (0.32)	0.476 (0.306)	0.602 (0.319)	-0.051 (0.034)
Change in hours	-0.313 (0.181)	-0.314 (0.166)	-0.332 (0.169)	-0.017 (0.065)

Note: All dependent variables in logarithm form. Standard errors are in parentheses. Statistical significance at the 1, 5 and 10% level denoted by ***, **, and *. Estimation based on 1850 observations. Mean conditional variance has only 1837 observations due to convergence problems in GARCH(1,1) estimation on 13 trading days.

Source: Own calculations

Considering WASDE reports, our results suggest that volatility is 80.8% higher on release days. This effect is thus four times greater compared to the impact of Russian grain trade policy news. Moreover, we find significant pre-announcement effects (Figure 19). Precisely, the δ_l^{wasde} coefficients are significantly elevated in the week before a WASDE release, while being considerably lower during the three days directly preceding the publication (i.e. at $l = 1, 2, 3$). The news agency Reuters routinely polls numerous grain analysts regarding expected WASDE supply and demand statistics, publishing results around one week prior to a report release. This publication likely explains the observed pre-announcement pattern, which thus depicts price adjustment processes in anticipation of upcoming WASDE statistics. After market participants formed their expectations, the market is relatively quiet in the days directly preceding a report release.[60] On days after publications, volatility reverts to levels observed on comparable regular trading days. Elevated volatility three days after a report publication is an exception to otherwise insignificant post-announcement effects.

The comparison with GASC tender openings reveals that these events are not associated with large volatility effects (Figure 19). However, it is notable that volatility is typically lower around GASC openings, while this effect is not significant at conventional significance levels. Precisely, the δ_l^{gasc} coefficients are mostly negative in the post-announcement period, i.e. with $l = -1, -2, \dots, -5$. We interpret this finding as weak evidence that information about competitive prices on physical markets provided in GASC tender results reduces pricing uncertainty in the short-run. Lower volatility directly prior to a tender opening also suggests that GASC officials tend to issue tenders in periods of relative calm on the CBoT futures market.[61]

60 Jones et al. (1998) refer to lower volatilty preceding news announcements as a 'calm-before-the-storm' effect.

61 News reports repeatedly point to a connection between the timing of GASC tenders and price movements on the CBoT wheat futures market (see e.g. Bloomberg, 2015).

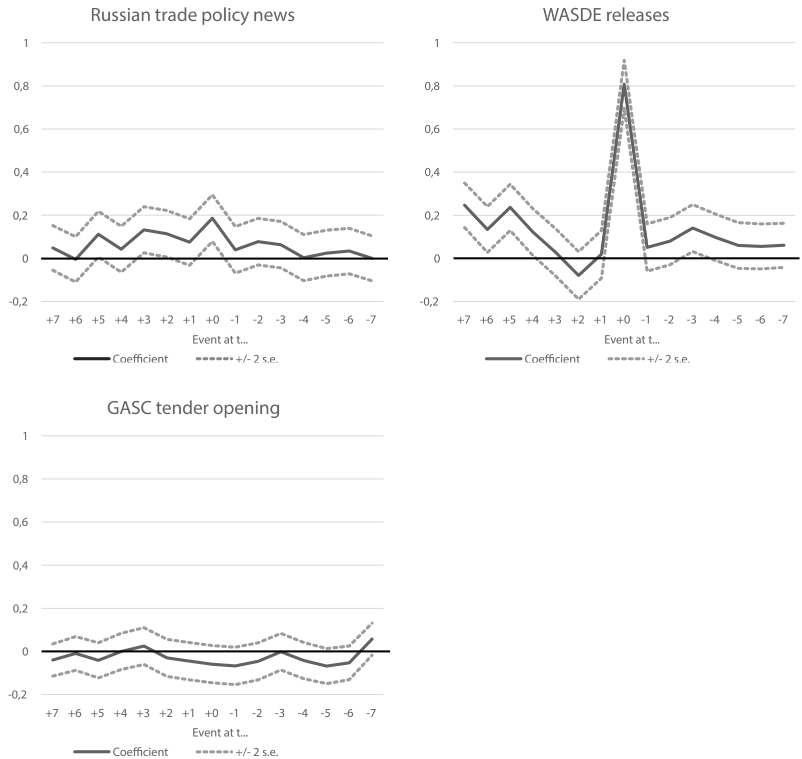

Figure 19: Visualization of estimated announcement effect

Note: Straight lines represent δ_l^k coefficients from to the benchmark model using jump-robust BV (Table 12). For better comparability, we present the same y-axes for the three event types.

Source: Own calculations

5.5.3 Model comparison: realized versus conditional variance

Estimating the $ARMA\text{-}X$ model using RV instead of BV series as dependent variable produces similar results. Small differences in the estimated contemporaneous effects (δ_0^k) of Russian grain trade policy news (0.150 versus 0.186) and WASDE reports (0.825 versus 0.808) provide weak evidence that the former news type affects price volatility, while the latter has a relatively larger effect on the price level, which is excluded from the BV_t but not from the RV_t series. This is in line with our findings regarding jump occurrence on respective event days (see section 5.1).

We further re-estimate our $ARMA\text{-}X$ model employing two conditional volatility series. Column three of Table 12 presents results from a series of mean conditional variance estimated using $GARCH(1,1)$ models and intraday price returns ($\overline{CV}_t^i$).[62] The estimated volatility effects of the considered news events are similar to results obtained from the realized volatility models and do not lead to qualitatively different conclusions. As an exception, the contemporaneous volatility on WASDE report release days is quantified markedly higher at 94.4%, versus 82.5% suggested by the RV model.

While the three models discussed so far build on the same database of intraday price returns, the fourth model (CV^d) is based on conditional variance estimated from daily open-to-close returns and does therefore not incorporate intraday information. Here, the $ARMA\text{-}X$ estimation results are notably different, as the only significant volatility effects are determined in the week preceding WASDE releases (see also Figure A8 in the appendix). All other contemporaneous and pre-announcement effects suggested by the intraday models are not apparent. This finding

62 Precisely, an individual GARCH(1,1) model is estimated for each of the 1850 trading days from 58 intraday price returns sampled at a five-minute frequency, assuming a normal return distribution. The mean is then calculated from the intraday conditional variance series. Due to convergence problems, intraday conditional variances could not be estimated on 13 trading days. The respective ARMA-X model is thus based on a series of only 1837 observations.

corresponds to Andersen et al. stating that 'models based on daily data such as *GARCH* [...] rely on long and slowly decaying weighted moving averages of past squared returns and therefore adapt only gradually to volatility movements' (2003, p. 613). *GARCH* models based on daily data therefore only depict volatility changes lasting for several days, while punctual, short-term effects that persist only for minutes or hours will necessarily be disregarded.

Focusing on seasonality, the four considered models jointly suggest that wheat price volatility is highest in May through to August, i.e. during the Northern hemisphere's growing and harvesting months. In this time period, (un-) favorable weather conditions have a profound effect on quality and size of the future crop, explaining the higher volatility. Conversely, volatility is lowest in the Northern hemisphere's winter months of November through to January. These findings are in line with Karali and Power (2013), Simon (2002), and Karali and Thurman (2010), who similarly find seasonality in grain price volatility. Regarding day-of-the-week effects, our results suggest that volatility is slightly higher on Thursdays compared to other weekdays. To ensure comparability, we estimate all *ARMA-X* models using one *AR* and one *MA* term. *AR* terms from the intraday volatility models are similar in size, ranging from 0.910 to 0.926, while MA terms lie between from -0.711 -0.736. Using this specification, all model residual series are free from autocorrelation for up to 20 lags.

5.6 CONCLUSIONS

This study is unique in using high-frequency intraday price data to analyze how news on grain export restrictions affects price volatility on futures markets. Focusing on Russian trade policy news, we find that CBoT wheat futures volatility is 19 percent higher when reports on restrictions are published by Interfax. Regarding effects on price levels, jumps are less frequent on Russia news days but are grater in size if they occur compared to the overall sample. These news effects are small compared to market responses to WASDE releases, which result in an increase in volatility of 81 percent, as well as more frequent and larger price jumps. However, while WASDE reports contain regular, standardized and comprehensive global supply and demand information, our Russian news indicator variable comprises heterogeneous news, ranging from few actual implementations to clarifications and denials. Thus, our finding suggests that the futures market is highly sensitive to Russian grain trade policy news, as volatility tends to increase even if restrictions are only mentioned. This underlines that news on export restrictions are of key importance to global grain markets. Due to possible policy reactions by other countries, their impact is difficult to assess, inducing policy uncertainty into the market. Disagreement among traders about the likelihood of an actual implementation of the respective trade restriction can also explain the observed volatility effects (Bunek and Janzen, 2015, Banerjee and Green, 2015).

We investigate pre- and post-announcement effects for an extended period of seven days before and after news events, respectively. Our results show that futures price volatility is significantly elevated on several days preceding the publication of news regarding Russian grain export restrictions. This finding corresponds to anecdotal evidence suggesting that rumors about Russian grain export restrictions frequently circulate in the CBoT wheat futures market (e.g. AgriCensus, 2018). A following denial by government officials could then be interpreted as public clarification regarding these speculations. Further, our results could be interpreted as evidence suggesting that individual market participants have access to information regarding upcoming policy news before it is published by Interfax. Assessing these findings in light of the EMH we can state that private information is incorporated in the price before it becomes public, while its eventual publication still coincides with an increase in volatility. We suggest that this seeming contradiction results either from information asymmetries, as market participants might not know whether an arriving news item is already incorporated in the price, or from unfulfilled expectation, as traders might have anticipated and positioned themselves for news containing other information.

Concerning WASDE releases, we determine significant pre-announcement effects in the week preceding publication. This finding clearly corresponds to releases of analyst poll results, which provide expectations of leading market intelligence firms regarding upcoming WASDE statistics. However, the effect of these company estimates is spread over several days in our model, as analyst polls are not released in systematic temporal distance to WASDE releases. Moreover, we find weak evidence that volatility is lower on and after GASC tender opening days. This suggests that physical spot market prices revealed in the tenders reduce pricing uncertainty on the CBoT futures market. However, generally we find that post-announcement effects are insignificant. This indicates that the considered market rapidly and efficiently incorporates incoming information, supporting the semi-strong form of the EMH.

Our results confirm that intraday data is necessary to adequately evaluate futures market responses to news arrivals. While volatility series based on intraday data exhibit similar descriptive statistics and suggest comparable announcement effects, such effects cannot be determined if conditional variance estimated from daily returns is considered. However conversely, intraday and daily approaches suggest similar seasonal patterns in wheat price volatility. This underlines that conditional volatility estimated from daily returns is well-equipped to depict longer-lasting effects, while punctual effects from news arrivals will be disregarded. Thus, a sound analysis of specific volatility drivers crucially depends on the chosen approach estimating volatility (Karali and Power, 2013). Designing identification strategies, researchers therefore need to carefully assess which frequency and data granularity is best suited for the specific analysis. In this respect, our analysis complements existing literature on export restrictions as volatility drivers (An et al., 2016, Rude and An, 2015, Dalheimer et al., 2017) by explicitly considering short-term volatility effects, which can have serious implications for market participants, but have been disregarded thus far.

While results obtained from our three intraday models are very similar, we determine realized-type approaches to be slightly superior for the studied purpose. As an advantage, the mean intraday conditional variance approach can portray intraday patterns and depict volatility responses in the minutes or hours succeeding news arrival. However, as we cannot determine the exact time the futures market learns about information contained in the Interfax newswires, this advantage of intraday conditional volatility models does not materialize in our case. We therefore consider the non-parametric RV and BV approaches as superior, as they will be unaffected by convergence failures, which can occur more or less frequently depending on the return distribution chosen to estimate intraday conditional variance.

Export restrictions can exacerbate existing price trends, resulting in more extreme price movements (Bouët and Laborde, 2016). Our results suggest that news regarding such restrictions also corresponds to higher short-term volatility on futures markets, increasing liquidity risk to market participants and affecting activity on physical markets. Food export restrictions are allowed under WTO law if they are imposed 'temporarily' to prevent 'critical' shortages that threaten domestic food security. However, the terms 'temporarily' and 'critical' are not clearly defined in the WTO guidelines, which essentially enables exporting countries to impose restrictions without legal consequences. Export restrictions might protect domestic consumers from (further) price increases,[63] but it will foremost harm consumers in importing countries, as well as domestic producers. The implementation of a Pigovian tax could help preventing or mitigating such negative externalities. Designed as a fee facing countries that restrict exports, the tax would discourage the initial implementation and could be transferred as income to consumers in import-dependent countries if restrictions are indeed introduced (Bouët and Laborde, 2017). However, as concrete steps regulating food export restrictions currently appear difficult to implement at the WTO-level, Mitra and Josling (2009) suggest that an exporter 'code of conduct' designed to mitigate the risk of cascading export restrictions could first be negotiated between an initial group of exporting countries, and subsequently be ex-

63 Djuric and Götz (2016) find that wheat export restrictions can indeed fail to dampen domestic food price inflation.

panded until a 'critical mass' can be reached. Escalating export restrictions induce volatility to grain markets and can amplify or create a food crisis, jeopardizing global food security.

This study quantifies volatility effects of news regarding Russian grain export restrictions. We therefore extend the agricultural economics literature analyzing news arrival effects, which has largely focused on market responses to USDA reports thus far. Furthermore, by focusing on pre-announcement effects spanning an extended period of seven days, we provide valuable insights into market anticipation of upcoming information. Our results are in line with the semi-strong form of the EMH, suggesting that new information is quickly and efficiently processed, while we find additional evidence that private information is incorporated into the market before publication of new information. We further confirm that intraday price data is better equipped for the analysis of volatility effects of news arrivals than daily price data. The detected short-term volatility effects of news about export restrictions show the key importance of such policy information. To avoid negative consequences of escalating trade restrictions in times of rising food prices, it appears vital that the international community works to increase the cost that exporting countries face when restricting food trade.

6 CONCLUSIONS

6.1 SUMMARY OF RESULTS

Over the past two decades, the Black Sea region, Russia in particular, has considerably increased its share in the world wheat market, becoming vital to global food security. This dissertation describes Russia's rise to the position of the world's largest wheat exporter, presents key characteristics and analyzes consequences resulting from the country's rapid ascent. The first, descriptive chapter provides background information. It focuses on food trade relations between Russia and four central trading partners in the MENA region, namely Egypt, Turkey, Saudi Arabia and Iran. Grain trade constitutes the primary component of the studied trade ties. Russia has a clear comparative advantage in producing wheat, barley and maize, versus the studied MENA countries, which largely exhibit arid or semi-arid climate conditions. The frequent introduction of trade restrictive measures in the context of bilateral political conflict suggests that the studied economic relations are affected by improvement or worsening in the respective political relations. However, since 2016 Russia's trade ties with the considered MENA countries have generally deepened. Further, a trend towards greater diversification of Russian food exports can also be observed. These trade expansions must be interpreted in the context of Russia's declared goal of increasing the value of food exports from 24 billion USD in 2019 to 45 billion USD by 2024 (Wegren, 2020).

Chapters 3 through to 5 provide econometric model estimations, which represent the analytical contribution of this dissertation. Narrowing the focus to one particular MENA destination market, namely the world's top wheat importer Egypt, an initial market integration analysis assesses price interdependencies and price leadership relations among key wheat exporters. Using a unique series of Egyptian tender prices, results of the estimated multivariate $VECM$ suggest strong market integration between the exporters Russia, France, USA and the importer Egypt. Tests for price leadership suggest that the French wheat export price can be considered as a price leader in the GASC tender market, while evidence for US price leadership is weaker. Previous studies (e.g. Ghoshray, 2006) have largely attributed a price leadership function to US export prices.

The findings, which are based on a dataset ranging from 2011 through to 2019, are therefore interpreted as a reflection of recent shifts in the patterns of physical wheat trade. Precisely, the US share decreased around 12 percentage points since the turn of the millennium, while Russia and Ukraine, as well as the EU have recorded considerable gains (see Figure A3). While we find no evidence of Russian price leadership in the Egyptian tender market, the weak exogeneity determined for French export prices suggests that Europe and the Black Sea region become increasingly central to the international soft wheat trade.

As opposed to rapid developments on physical markets, the global wheat futures market landscape is slow to adapt to the rise of Russian wheat exports. Several exchanges such as the CME, the EPA or the MOEX attempt to establish a functioning futures market for Black Sea wheat. Among these attempts, the CME's BWF swap contract is the sole market recording continuous trading activity to date. However, its liquidity remains negligible compared to volumes traded at established wheat futures markets in the USA or the EU. Traders in the Black Sea region there-fore use established wheat futures contracts for price risk management, which can involve basis risk. Against this background, the fourth chapter analyzes the relations between Russian spot and CBoT, as well as EPA wheat futures prices. Results of *VAR-X* estimations confirm that price movements on the French EPA wheat futures market affect the Russian spot market. Further evidence suggests that the CBoT futures market responds to price changes in the Russian physical market. Both findings are therefore in line with results obtained in Chapter 3. Moreover, all an-alyzed wheat markets are affected by jumps in the ruble exchange rate. Controlling for asymmetries, we find that Russian wheat export prices respond more strongly to ruble appreciations than depreciations. This result is interpreted as evidence suggesting imperfect competition in the Russian grain export sector, as it indicates that USD-denoted export prices are more likely to rise in response to changes in the exchange rate than they are to fall.

In the past, Russia has frequently restricted grain exports to dampen domestic food price inflation, which can have severe consequences for global food security. The third econometric analysis uses high-frequency data from the CBoT wheat futures market to quantify the effect of news regarding Russian grain export restrictions on intraday, seasonally adjusted realized volatility. Results suggest that Russian grain trade policy news significantly increase volatility on the CBoT wheat futures market. Elevated volatility is also determined on days before such news is published. Evidence for post-announcement effects is not found. While the volatility effects are minor compared to market reactions to pre-scheduled WASDE publications, they still underline the key importance of trade policy news with respect to futures price formation. As the imposition of one export restriction can lead to spiraling policy responses by other exporting or importing countries, its conclusive effect is difficult to assess for market participants. This partly explains the significant uncertainty induced by news regarding Russian grain trade policy. Further, the findings regarding pre-announcement effects are in line with anecdotal evidence pointing to repeated circulation of rumors regarding possible Russian export restrictions. These rumors can induce volatility to the studied market, even if no restrictions are in fact imposed. The results suggest that the semi-strong form of the EMH holds for the considered market. Incoming information is incorporated without delay, suggesting that market prices reflect all publicly available information.

The conducted analyses also provide insights concerning questions of econometric modelling. Due to available freight cost data, the interpretation of $VECM$ constant terms as proxies for transaction costs can be empirically assessed in Chapter 3 (see section 3.4.1 and Table 4). While often assumed, such tests for statistical equality of actually observed and implied transaction costs have not been conducted in the literature so far, to the best of the author's knowledge. Furthermore, the proportional adjustment techniques used to construct continuous futures price series (section 4.3) enable the construction of unbiased futures return series, which can be employed in volatility analyses. While potentially affecting model estimations, such futures price adjustment techniques are similarly not discussed or applied in the agricultural economics literature thus far. Moreover, a detailed comparison between different approaches to estimating daily futures price volatility from intraday data (namely, $GARCH$ and RV approaches) is provided in section 5.5. A detailed discussion on how different approaches affect the estimation of news volatility effects has also not been conducted in the literature thus far to the best of the author's knowledge.

6.2 LIMITATIONS

The conducted analyses are limited by the availability and nature of the employed databases. Econometric price analysis typically requires the used time series to be evenly spaced over time, exhibiting a constant frequency. However, regarding Chapter 3 the GASC tender prices are recorded irregularly and must therefore be converted to a constant monthly frequency. This adjustment procedure implies a loss of information as some individual tender prices will be disregarded. Alternatively, an analysis conducted at a higher (e.g. weekly) frequency would result in a large share of missing observations.

Further, the period of investigation is limited by the non-availability of Russian export prices between August 2010 and June 2011 due to the grain export ban. Consequently, results of the multivariate cointegration tests must be interpreted in light of dimensionality problems (Asche et al., 2012). Precisely, the inclusion of an increasing number of market locations to a multivariate cointegration framework estimated from a small dataset can rapidly use up degrees of freedom and lead to unstable results. In our case, the finding that export prices recorded in Canada, Australia, Kazakhstan, and Argentina are excluded from the GASC tender market could be a consequence of a limited number of observations, instead of actual independence of the respective markets. Wheat quality differences between the respective regions can be considered as additional factor affecting the results of the multivariate cointegration tests.

Moreover, the analysis in Chapter 3 explicitly links the size of $VECM$ constant terms to average observed freight costs. However, it must be noted that the resulting implicit assumption of transportation costs being a constant proportion of the respective FOB prices likely does not hold in practice. However, this part of the analysis should still be considered as a valuable contribution, as analyses employing *VECM* to study spatial market integration generally do not discuss the role of transportation costs, because such data is rarely available.

The econometric analysis in Chapter 4 is based on a series of Russian wheat export price indices, which shows zero-returns on 40% of days. As this finding suggests that trading activity is slow on the studied physical market, an analysis based on a daily frequency does not appear warranted. Estimations are therefore conducted based on a lower, weekly frequency. However conversely, this weekly frequency appears low if highly liquid futures markets are concerned. Thus, while the conducted analysis investigates spot-futures relations, the chosen frequency and model speci fications cater to the speed of economic activity on physical markets. Short-term volatility interdependencies between the two studied futures markets, which can be expected to exist (see Hernandez et al., 2014, Yang et al., 2003), are thus likely not determined within the estimated *VAR-X* model (see Table 9) due to the choice of a lower frequency.

A further limitation stems from time differences between the markets studied in Chapter 4. As a consequence, temporal interdependence could partly result from prices reflecting different sets of information due to non-equal market closing times. While recent research has employed techniques to synchronize return series (Hernandez et al., 2014), other studies do not adress time zone differences (e.g. Arnade and Hoffmann, 2019). Future research should systematically investigate potential biases arising from neglecting time zone differences and assess and compare different approaches to adjusting estimations to control for differences in market closing times.

Regarding the estimated effect of trade policy news publications on intraday futures price volatility, an important shortcoming is that it cannot be determined, whether the news agency Interfax is actually first to Sdeliver the respective news to the CBoT futures market. While the finding that volatility is significantly higher on Interfax publication days suggests that the Russia & CIS Business and Financial Newswire reports timely on current developments regarding Russian grain trade policy, it cannot be ruled out that other news services provide this information prior to Interfax, which would explain the determined pre-announcement effects (see Table 12). However, under this assumption the presented conclusion regarding the EMH remain valid, because a faster news agency should be considered as provider of private information, as its service is not publicly accessible.

We attribute significant volatility effects prior to Interfax news releases to rumors regarding Russian grain trade policy circulating in the wheat futures market. While this explanation is in line with anecdotal evidence (AgriCensus, 2018, Sowell, 2019), rumors cannot unequivocally be determined as factor explaining pre-announcement effects. It cannot be ruled out that an unknown, third factor drives the con temporaneous, as well as the pre-announcement effects. In this respect, futures research could further investigate the role of rumors in explaining volatility on financial markets. It will be particularly interesting to process and incorporate data from social media platforms such as *Twitter* or *Reddit* into model estimations similar to the analysis conducted in Chapter 5 to assess potential correlations between the circulation of information and financial market volatility.

6.3 POLICY RECOMMENDATIONS AND BUSINESS IMPLICATIONS

Russia has superseded the USA as leading exporter on the world wheat market and has become vital to ensuring global food security. Against this background, the repeated imposition of food export restrictions represents a fundamental challenge not only to countries depended on wheat imports, but to the international food trade system as a whole. Trade restrictions imposed by large exporting countries exacerbate price surges on international markets and increase short-term volatility on futures markets. Therefore, it must be recommended that governments refrain from the imposition of food export restrictions. The negative effects that particularly low-income importing countries have to bear can be severe, while the intended price dampening effects on domestic markets remain generally doubtful (Djuric and Götz, 2016, Glauben et al., 2015) and certainly minor compared to the risk imposed to the food supply in other countries. Particularly in periods of global crises and high uncertainty, as encountered in the course of the Covid-19 pandemic, more and not less international coordination and cooperation is warranted (Heigermoser and Glauben, 2021). While a focus on narrow national or regional interests might appear unavoidable to policy makers in complex crisis situations, it is also evident that global crises demand for global coordination (Pies, 2020).

Reaching the SDG No. two of zero hunger for a growing world population must clearly be seen as a global challenge requiring such international cooperation. Frictionless international agricultural trade is essential to ensuring global food security, as climatic and soil conditions make sufficient food production impossible in certain regions (see Chapter 2), while favoring surplus production in others. Against this background, it is vital to strengthen the rule-based international food trade system, ideally on the level of the WTO. In this context, it must be pro blematized that countries are currently allowed under the GATT to restrict food exports practically without direct legal consequences, due to a lack of legal clarity regarding the definition of the terms 'temporarily' and 'critical' in Article XI, 2a, which regulates food trade restrictions (GATT, 1986, Bouët and Laborde, 2016). At minimum, a clearer definition of these terms would not only hamper the introduction of trade restrictions generally, but also help to make the risk of such policy changes more calculable to market participants. Precisely, the likelihood of actual implementation could be assessed based on concrete indices reflecting how 'critical' a domestic food shortage is, such as a transparent measure of domestic food price inflation. This will contribute to a dampening of short-term futures price volatility effects of news on export restrictions, which were determined in Chapter 5.

Going beyond definitional revisions, a Pigouvian tax designed as a fee to countries introducing food export restrictions would serve as disincentive to implement such policies (Bouët and Laborde, 2017). Ideally, the funds collected by this tax could be used to finance the World Food Programme to ultimately benefit consumers in countries negatively affected by the rise in food prices that resulted from the imposed restrictions. However, adjustments to WTO law currently appear rather unlikely, as negotiations within the Doha Development Round remain stalled since 2013. Thus, it is alternatively recommended that arrangements aiming to discourage food export restriction are first agreed among a core group of grain exporting countries (see also Mitra and Josling, 2009). In this respect, the EU, which also increased its share in the world wheat market recently and is typically the world's second largest exporter (see Figure 1) should take on a leading role in promoting unimpeded food trade.[64] This is particularly relevant as EU wheat prices became more important to price formation on the world wheat market (Chapter 3) and regarding price dynamics on the Black Sea spot markets in particular (Chapter 4). If the core group of exporting countries committed to free food trade is sufficiently large, this could increase the pressure on other exporters to similarly refrain from future food export restrictions.[65] In any way, it is of utmost importance for the international community to prevent future food price crises by increasing the cost that countries face when restricting food trade. This is particularly vital as global wheat production can be expected to become increasingly volatile due to more frequent extreme weather events induced by climate change, implying higher risk of harvest shortfalls (Wheeler and von Braun, 2013).

Attempts by futures exchanges to establish a functioning Black Sea wheat futures market are in early stages. Market participants operating on Black Sea grain markets therefore face a trade-off between basis

64 During food price crisis occurring in 2007/08 and 2010/11, import policy decisions by the EU in fact exacerbated price surges in a similar fashion as export restrictions by Black Sea exporters and other countries (Pies, 2020).

65 In this respect, it is worth repeating that only eight wheat exporters account for around 90% of world wheat exports (see Figure 1).

and liquidity risk regarding the selection of a futures contract suitable to hedge price risk in the region. The CBoT futures market shows high liquidity, but can exhibit price divergences especially with geographically distant physical markets, which exposes Black Sea market participants to locational basis risk (see section 4.2). The EPA futures market is more closely related to Russian wheat prices, but also characterized by lower trading volume. This implies liquidity risk as the timely entry and exit into the respective futures market can be impeded by a lack of price quotes, which is of special concern to holders of larger positions (Vollmer et al., 2021). As the CME's BWF swap contract shows even smaller trading volume compared to the EPA futures contract, this issue is even more pronounced concerning this novel derivative. Until a genuine Black Sea wheat futures market gains sufficient liquidity, market participants have to balance basis and liquidity risks associated with the mentioned futures markets in their risk management operations.

Particularly concerning the futures market landscape, this dissertation has shown that the transformation induced by Russia's ascent on the world wheat market is still ongoing (see section 4.2, specifically). To businesses active in global grain markets this implies a continued necessity to improve the understanding of the functioning of Black Sea grain markets. This is particularly relevant since established information services assessing global grain production have severely over- or underestimated Russian wheat production in the past. To exemplify, the USDA's World Agricultural Outlook Board, which publishes the monthly WASDE reports has initially estimated the Russian 2017/18 wheat production at 67 million tons in May 2017 (WASDE, 2021c). However, this forecast underestimated the actual Russian production by 21%. To compare, the USDA's initial estimate of the US crop was overestimated by only 4.6% (see Figure A9 in the appendix). This clearly suggests that there is potential for market information agencies to develop systems that can provide more accurate forecasts regarding the novel center of world wheat production. Several private companies already offer alternative forecasts to complement WASDE estimates, as portrayed in Chapter 5. In this respect, future research could further assess the accuracy of private versus public forecasts in an approach similar to Karali et al. (2019) but focusing on Black Sea production figures.

6.4 OUTLOOK

Grain exports restrictions remain a policy instrument frequently applied by the Russian government. Most recently, the ministry of agriculture announced a novel floating tax for wheat, maize, and barley exports in early 2021 (USDA, 2021b). Due to the complex system of calculating the precise amount of the duty, this policy introduces additional uncertainty to exporters of Russian grain, especially when delivery periods further into the future are concerned (Bloomberg, 2021). Further, in order to receive clearance for export, trading companies are required to report transaction details to the MOEX, which aims to use this information to construct an independent wheat price index. This can be interpreted as an attempt to provide an additional pricing benchmark reflecting Russian wheat prices to compete with the index provided by S&P Global Platts, which was described and used in in the analysis in Chapter 4. Potentially, this MOEX price index could be used as settlement price for a Russian wheat swap contract competing with the CME's BWF derivative in the future. As outlined in section 4.2, it remains an open question whether a functioning Black Sea wheat futures market can be established and which exchange will be able to offer it. However, as trading volume is the decisive factor determining the success of a futures contract (Garcia and Leuthold, 2004), it appears unlikely that several, similar Black Sea wheat futures contracts will ultimately coexist.

A further, key development regarding Russian grain trade is the increasing interference of government actors in transport and export infra structure. Recent reports suggest that state-controlled organizations have taken over several companies operating ports, railway, storage, and transshipment infrastructure. These acquisitions reportedly aim at creating a vertically integrated Russian grain holding company, allowing the government 'greater control over exports' (Reuters, 2019a). Certainly, comments suggesting that these efforts constitute an attempt to use 'wheat as a geopolitical weapon' (Agritel, 2020) are exaggerated. However, particularly the stated objective to impede operations of 'foreign' private trading companies in the Russian export sector (Reuters, 2019b) is concerning from the perspective of global food security. Competition between numerous trading companies in an export market ensures that prices reflect marginal costs of production. Increased concentration can result in inefficiencies, the exercise of market power and price mark-ups. These will ultimately be transmitted to importing countries, causing higher consumer prices that jeopardize food security, particularly in lower-income regions. This development is particularly worrying as global food prices have increased steadily since mid-2020 and have reached a ten-year high in May 2021 (FAO, 2021, see also Heigermoser and Glauben, 2021). Against this background, future research should focus on the identification of potential market power in the Russian grain sector and aim to quantify the effects of government intervention. While the finding of asymmetric responses to appreciations versus depreciations in the ruble exchange rate reported in section 4.5.3 can serve as a starting point, more thorough analyses should also investigate how movements on foreign exchange markets affect the domestic grain markets in Russia.

It is the declared goal of the Russian government to increase the value of food exports from 24 billion USD in 2019 to 45 billion USD in 2024 (Wegren, 2020). It can be expected that Russia will continue to expand the base of destination markets to increasingly serve grain to more geographically distant market in South and South East Asia or Sub-Saharan Africa. It further appears likely that Algeria will decide to allow the import of Russian wheat in the future, following a similar decision by Saudi Arabia (Reuters, 2019). Russian food exports are also likely to further diversify, as certain meat and vegetable products can be expected to play a more salient role versus grain exports in the future. Yet, increasing importance as a major food exporter comes with increased responsibility. Russia, as well as other major exporting countries should commit to frictionless and unimpeded food trade and refrain from export restrictions to ensure sufficient food supply to a growing world population.

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APPENDIX

FIGURES IN APPENDIX

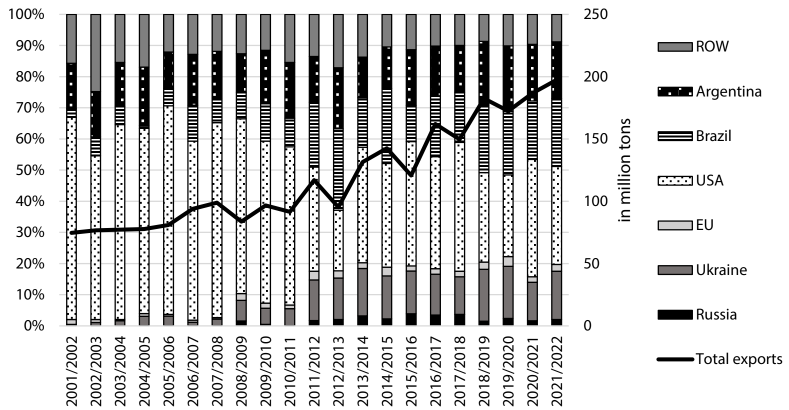

Figure A1: Market shares of world's top corn exporters

Note: Line refers to right y-axis. Values for season 2021/2022 are estimates by the USDA.

Source: Own illustration based on USDA (2021)

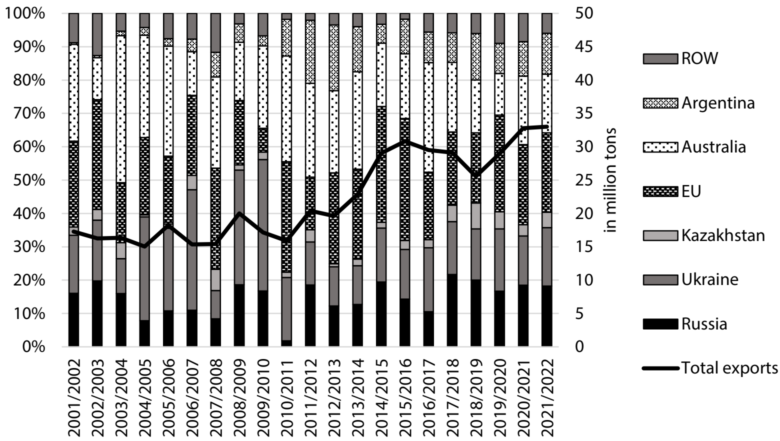

Figure A2: Market shares of world's top barley exporters

Note: Line refers to right y-axis. Values for season 2021/2022 are estimates by the USDA.

Source: Own illustration based on USDA (2021)

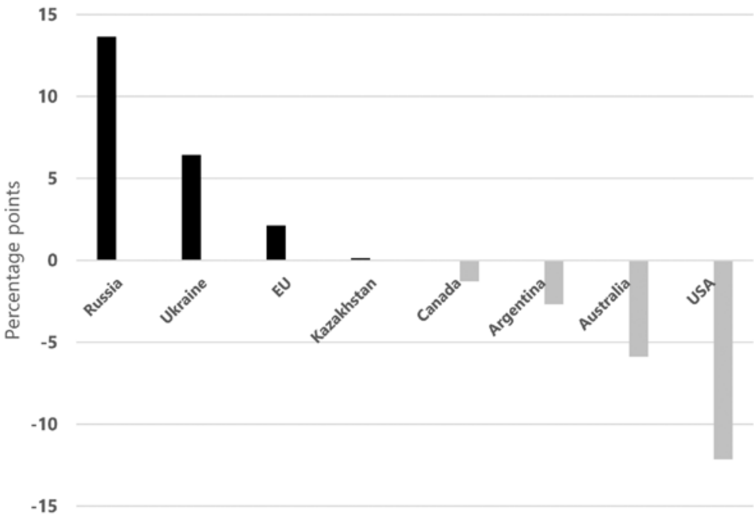

Figure A3: Changes in wheat export shares, 2000/01–2004/05 versus 2016/17–2020/21

Note: The presented eight exporters accounted for more than 90% of world wheat exports in 2020/21.

Source: Own illustration based on USDA (2021)

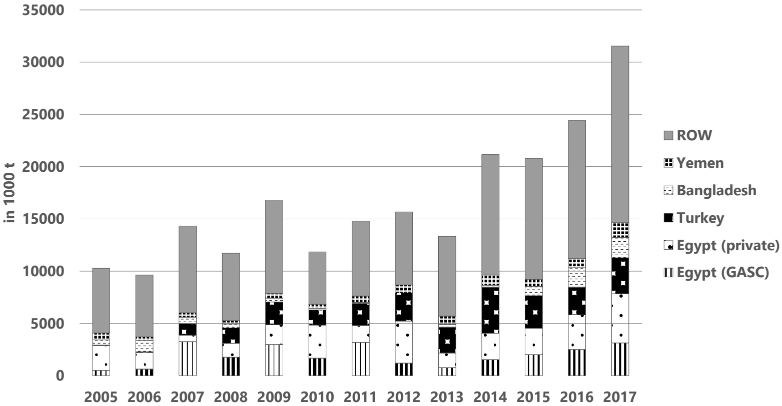

Figure A4: The largest five wheat export markets for Russia, 2005-2017

Note: Export volumes to Egypt (private) are obtained by subtracting Russian exports to the GASC from the total exports to Egypt. ROW denotes 'Rest of World'. The largest five export markets are selected based on shares in 2017.

Source: Own illustration based on UN Comtrade (2020) and Zerno Online (2020)

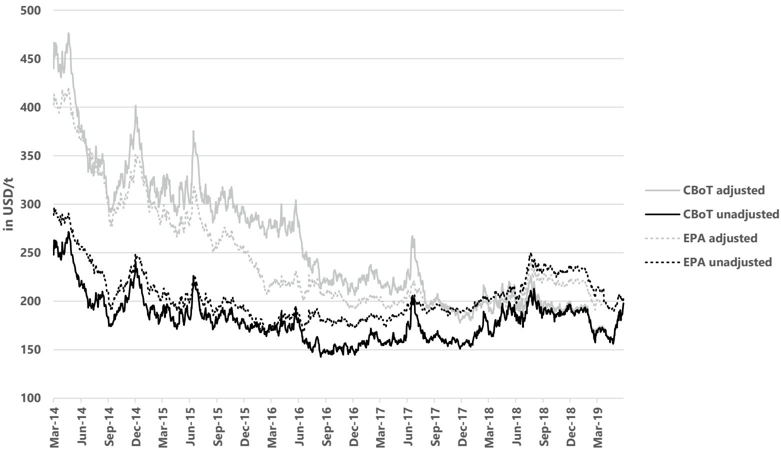

Figure A5: Backward ratio-adjusted versus unadjusted futures prices

Note: Futures price series adjusted using backward ratio adjustments as outlined in section 4.3.

Source: Own illustration based on AHDB (2019)

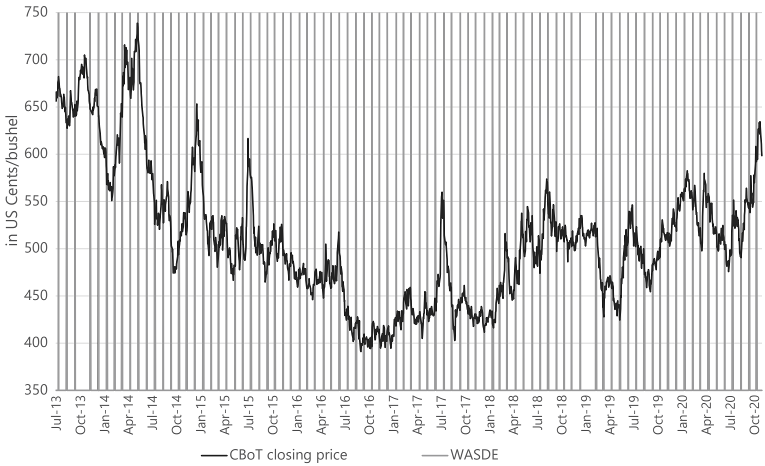

Figure A6: CBoT closing prices and WASDE publication days

Note: Vertical lines represent 86 WASDE release days. In October 2013 and January 2019 no WASDE reports were released due to US government shutdowns.

Source: Own illustration based on USDA (2021) and Tick Data (2020)

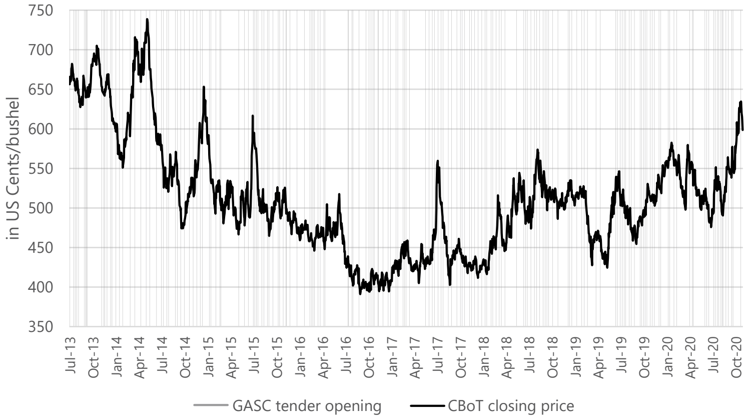

Figure A7: CBoT closing prices and GASC tender opening days

Note: Vertical lines represent 181 GASC tender opening days. Tenders are less frequent in March through to May, during Egypt's domestic harvesting season.

Source: Own illustration based on Zerno Online (2020) and Tick Data (2020)

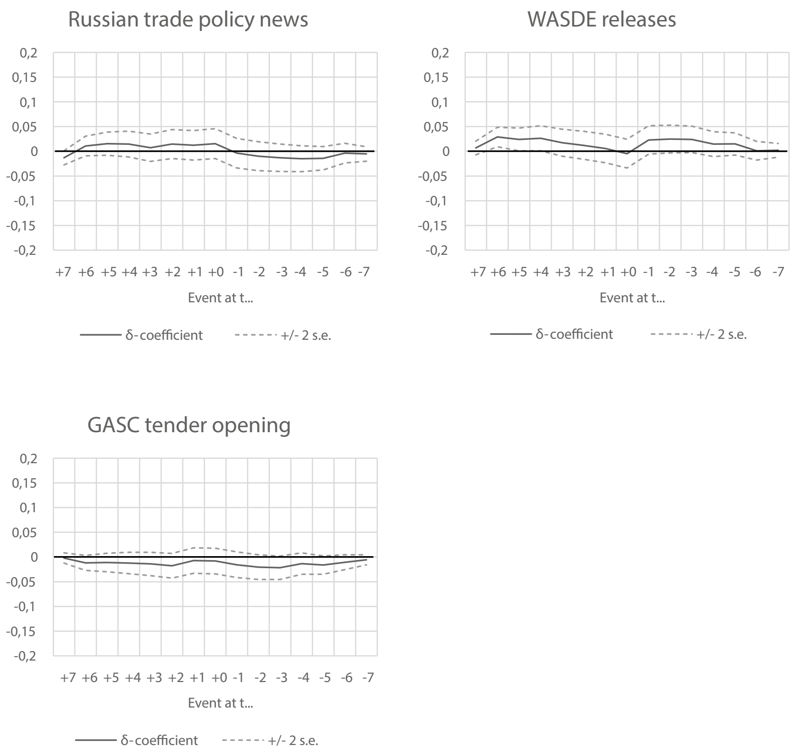

Figure A8: Visualization of estimated announcement effects using CV^d

Note: Straight lines represent δ_i^k coefficients from to the model using conditional variance estimated from daily returns (Table 12). For better comparability, we present the same y-axes for the three event types.

Source: Own illustration

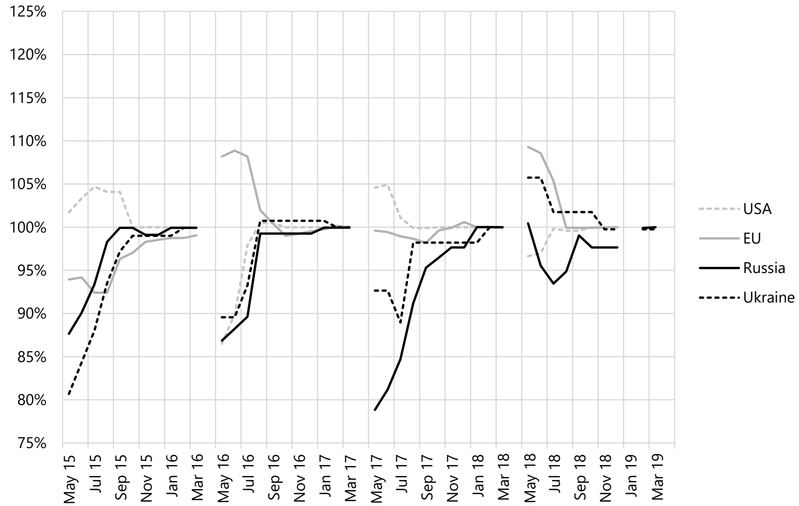

Figure A9: Deviations of WASDE wheat production forecasts

Note: Lines depict deviations in each monthly WASDE report versus each year's April report. The April report is defined as the final estimate, as May reports contain the USDA's first estimate of upcoming production.

Source: Own illustration based on USDA (2021c)

TABLES IN APPENDIX

Table A1: Key characteristics of major wheat procurement agencies

	GASC	OAIC	SAGO
Country	Egypt	Algeria	Saudi Arabia
Organization's imports	5.5 mmt (49%)	5.7 mmt (73%)	3.1 mmt (91%)
Average volume per tender	207.640 mt	507.692 mt	624.273 mt
Top sources of wheat in 2016	Russia (51%), Ukraine (24 %)	France (43 %), Canada (13%)	Germany (44%), Poland (22%)
Tender frequency (days)	12	29	68
Main port	Alexandria	Algiers	Jeddah (Dammam)
Distance to Russia's port of Novorossiyk (in nautical miles)	1178 nm	1840 nm	1965 (4363) nm

Note: Averages are calculated based on data for seasons 2013/14 through 2016/17. Tender frequency calculated as total number of calendar days divided by tenders issued. Mmt denotes 'million metric tons'.

Source: Own presentation based on Zerno Online (2020)

Table A2: Seller concentration within GASC tenders

Season	HHI	CR4	CR8	Total sellers	Total sellers of Russian wheat
2011/12	0.107	53%	88%	16	12
2012/13	0.108	55%	80%	16	6
2013/14	0.087	46%	77%	17	9
2014/15	0.083	45%	73%	16	9
2015/16	0.091	48%	80%	18	12
2016/17	0.075	42%	65%	22	15
2017/18	0.146	65%	86%	18	14
2018/19	0.091	48%	77%	18	12

Note: CR4 (CR8) refers to the combined market shares of the top 4 (8) suppliers. Herfindahl-Hirschman Index (HHI) is calculated as the sum of the squared market shares of all companies delivering at least one cargo to the GASC within the regarding season.

Source: Own calculations

Table A3: Descriptive statistics of price series used in VECM estimation

	Min.	Mean	Max.	St. Dev.	Skewness	Kurtosis	NAs
Argentina	168	251.9	372.5	57.3	0.55	2.09	0
Australia	172.2	251	347	43.8	0.30	2.34	0
Canada	202.8	293.5	448.2	66.2	0.55	2.02	0
France	166.8	236.9	351.8	50.7	0.61	2.24	0
GASC	178	254.5	373.9	49.1	0.51	2.27	16
Kazakhstan	154.2	217.2	355	52.6	0.84	2.67	0
Russia	167	237.9	365	51.4	0.77	2.77	0
Ukraine	167.4	234.2	345	47.6	0.64	2.47	0
USA	157.5	227.1	346.4	46.5	0.65	2.64	0

Note: Sample period runs from July 2011 to June 2019 (96 observations).
Minimum, average, maximum and standard deviation expressed in USD/t.

Source: Own calculations

Table A4: Top exporters' share on world wheat and Egyptian wheat tender market

	World wheat market		Egyptian wheat tender market	
Exporter	2011/12 – 2014/15	2015/16 – 2018/19	2011/12 – 2014/15	2015/16 – 2018/19
Russia	11.9%	18.3%	37.0%	63.0%
European Union	17.1%	15.3%	--	--
• France	--	--	18.7%	6.2%
• Romania	--	--	19.9%	18.1%
USA	17.9%	14.0%	9.1%	2.2%
Canada	13.4%	12.4%	0.6%	0.0%
Ukraine	5.4%	9.7%	10.6%	8.4%
Argentina	3.9%	6.8%	2.2%	1.3%
Australia	12.6%	8.6%	0.0%	0.0%
Kazakhstan	5.1%	4.5%	1.2%	0.0%
ROW	12.7%	10.3%	0.6%	0.8%

Note: USDA reports aggregate export quantities for the European Union, while Zerno Online records GASC imports from single EU countries. Typically, France is the EU's largest wheat exporter, followed by Romania.

Source: Own presentation based on USDA (2021) and Zerno Online (2020)

Table A5: Results of ADF unit root and KPSS stationarity tests

	ADF test			KPSS test		
	Price in levels		Price in differences	Price in levels		Price in differences
	Intercept	Intercept + Trend	Intercept	Intercept	Intercept + Trend	Intercept
Argentina	-2.02	-2.35	-6.30***	0.77***	0.15**	0.09
Australia	-1.53	-1.67	-8.19***	0.43*	0.17**	0.11
Canada	-1.97	-2.14	-9.58***	1.03***	0.25***	0.16
France	-1.67	-1.78	-7.20***	0.82***	0.21**	0.13
GASC	-1.14	-1.74	-8.40***	0.76***	0.19**	0.09
Kazakh-stan	-2.69*	-3.20*	-6.44***	0.61*	0.11	0.07
Russia	-1.09	-1.75	-8.30***	0.77***	0.17**	0.12
Ukraine	-1.32	-1.91	-7.93***	0.79***	0.18**	0.10
USA	-1.56	-1.81	-8.86***	0.93***	0.19**	0.14

Note: Table reports t-statistics and LM-statistics for ADF and KPSS tests, respectively. Sample runs from July 2011 to June 2019. All prices are in lateral logarithms. Null hypothesis for ADF test is series has a unit root against alternative of stationarity. Null hypothesis for KPSS test is series stationary against alternative of non-stationarity. Lag length determined using the Schwarz Information Criterion for ADF and the Newey-West bandwidth method for KPSS tests. One-sided p-values for ADF test are from MacKinnon (1996). P-values for KPSS test are from Kwiatkowski et al. (1992). ***, ** and * denote rejection at the 1, 5 and 10 percent level of significance, respectively.

Source: Own calculations

Table A6: Bivariate long-run equations with dummy variable for imputed observations

	GASC-Russia	GASC-France	GASC-USA
Unrestricted long-run price transmission parameters			
Price transmission elasticity β_1^i	0.913 [0.030]	0.903 [0.030]	0.885 [0.042]
Parameter of interaction dummy $\beta_{1,d}^i$	-0.077 [0.067]	-0.060 [0.065]	0.049 [0.099]
Constant β_0^i (for unrestricted β_1^i)	0.544 [0.163]	0.600 [0.161]	0.614 [0.226]
Dummy shift for constant β_0^i	0.399 [0.370]	0.320 [0.358]	-0.278 [0.543]
Testing Law of One Price			
Wald test: $\beta_1^i = 1$	(0.005)	(0.002)	(0.007)
β_0^i (for $\beta_1^i = 1$)	0.074 [0.006]	0.075 [0.006]	0.115 [0.008]
Implied vs. observed freight costs			
Implied transaction costs, $tc_t^i = \beta_0^i \times \bar{p}^i$	= 17.6 USD/t	17.8 USD/t	26.1 USD/t
Average observed freight costs, $\overline{tc}^i$	13.5 USD/t	15.5 USD/t	29 USD/t
Wald test on equality of implied and observed freight costs: $\beta_0^i = \frac{\overline{tc}^i}{\bar{p}^i}$	(0.006)	(0.125)	(0.129)

Note: Cointegrating vectors are normalized to represent pairwise cointegration with GASC tender prices. Standard errors are in []. P-values are in ().

Source: Own estimations

Table A7: Descriptive statistics of wheat spot and futures return series

	Russian spot	CBoT futures	EPA futures
Mean	0.000	-0.001	-0.001
Standard deviation	0.006	0.016	0.011
Minimum	-0.039	-0.06	-0.045
Maximum	0.031	0.066	0.046
Skewness	-0.015	0.300	0.204
Excess Kurtosis	6.899	0.684	1.142
Ljung-Box χ^2 statistic	310.4 [0.000]	58.5 [0.191]	61.4 [0.129]
Zero-return share	40.5%	1.4%	6.9%

Note: p-values are in [].Ljung-Box statistic based on 50 lags of autocorrelation coefficients. Futures prices are ratio-adjusted following the procedure laid out in section 4.3. Zero-return share calculation based on EPA series denoted in EUR/t.

Source: Own illustration based on S&P Global Platts (2019) and AHDB (2019)

Table A8: Results of VAR-X estimation with signed weekly exchange rate returns

Endogenous variable (k =)	Black Sea	CBoT	EPA
Constant (α^k)	0.004** (0.002)	0.016*** (0.004)	0.009*** (0.002)
Russia lag one ($\beta^k_{rus,1}$)	0.184*** (0.065)	0.271** (0.129)	0.06 (0.083)
CBoT lag one ($\beta^k_{cbot,1}$)	0.028 (0.035)	0.082 (0.07)	0.015 (0.044)
EPA lag one ($\beta^k_{epa,1}$)	0.118** (0.055)	0.076 (0.109)	0.272*** (0.07)
Russia lag two ($\beta^k_{rus,2}$)	-0.054 (0.064)	-0.131 (0.128)	0.114 (0.082)
CBoT lag two ($\beta^k_{cbot,2}$)	-0.026 (0.035)	0.096 (0.07)	-0.011 (0.045)
EPA lag two ($\beta^k_{epa,2}$)	-0.002 (0.056)	0.09 (0.111)	0.181** (0.071)
Russia lag three ($\beta^k_{rus,3}$)	0.165*** (0.063)	0.211* (0.126)	-0.104 (0.081)
CBoT lag three ($\beta^k_{cbot,3}$)	0.03 (0.035)	0.094 (0.07)	0.003 (0.045)
EPA lag three ($\beta^k_{epa,3}$)	0.026 (0.054)	-0.079 (0.108)	0.096 (0.069)
Ruble return lag one (γ^k_1)	0.050** (0.022)	0.047 (0.044)	0.047* (0.028)
Asymmetry lag one (θ^k_1)	-0.001 (0.001)	0.002 (0.002)	-0.001 (0.001)
Ruble return lag two (γ^k_2)	-0.048** (0.022)	0.005 (0.044)	-0.003 (0.028)
Asymmetry lag two (θ^k_2)	0 (0.001)	-0.002 (0.002)	0.001 (0.001)
Ruble return lag three (γ^k_3)	-0.005 (0.022)	-0.008 (0.045)	0.027 (0.028)
Asymmetry lag three (θ^k_3)	0.001 (0.001)	0.002 (0.002)	-0.001 (0.001)
Spring (η^k_{spring})	-0.001 (0.001)	0.005** (0.002)	0.002 (0.002)
Summer (η^k_{summer})	-0.001 (0.001)	0.003 (0.003)	0.001 (0.002)
Fall (η^k_{fall})	-0.001 (0.001)	-0.001 (0.002)	-0.001 (0.002)
Shorter week (η^k_{short})	-0.002 (0.002)	0.001 (0.004)	-0.003 (0.002)
Adjusted R^2	0.152	0.144	0.268
Portmanteau χ^2 test statistic		30.622 [0.287]	
Log Likelihood		2708.199	

Note: Standard errors in (). P-values in []. Statistical significance at the 1, 5 and 10% level denoted by ***, **, and *. Null hypothesis of Portmanteau χ^2 test statistic is no autocorrelation. Test refers to no autocorrelation for up to six lags.

Source: Own estimations

Table A9: Russian grain export policy news, 2013-2020

Date	Weekday	Moscow Time	Title
02.12.14	Tuesday	8:05 pm	Russian exporters concerned by possible grain export restrictions in 2015
04.12.14	Thursday	12.01 pm	Russia to continue exporting grain, govt not discussing restrictions
09.12.14	Tuesday	3:52 pm	Russia not considering restrictions on grain exports - Dvorkovich
16.12.14	Tuesday	6:08 pm	Russian Agriculture Ministry not discussing grain export ban
22.12.14	Monday	1:03 pm	Russian govt imposing grain export duties - Dvorkovich
24.12.14	Wednesday	7:20 pm	Russian grain export duty won't be 'prohibitive' - source
25.12.14*	Thursday	8:03 pm	Grain export duty to be in effect from February to mid-2015 - Dvorkovich
19.01.15*	Monday	6:55 pm	Not wise to ban grain exports – Dvorkovich
27.02.15	Friday	10:22 am	Russia to consider changing wheat export duties in March - Dvorkovich
11.03.15	Wednesday	3:38 pm	Agriculture Minister Fyodorov: no plans to change size of wheat export duty
02.04.15	Thursday	11:15 am	Russia might keep wheat export duty beyond July 1
03.04.15*	Friday	4:34 pm	Grain export duty more likely to be prolonged than cancelled ahead of schedule – Dvorkovich
04.04.15*	Saturday	12:12 pm	No reasons to lift export duty on grain earlier than planned - Russian agriculture minister
07.04.15	Tuesday	6:08 pm	Grain export duty to be decided on in May-June – Fyodorov
15.04.15	Wednesday	2:55 pm	Russian Agriculture Ministry against lifting export duty on wheat before July 1, 2015
29.04.15	Wednesday	4:41 pm	Grain export duty may be reduced to zero in near future - Dvorkovich
05.05.15	Tuesday	5:45 pm	Russian AgMin suggests introducing new formula for grain export duty
07.05.15	Thursday	11:02 am	New Russian wheat export duty formula might take effect July 1 - paper

Date	Weekday	Moscow Time	Title
15.05.15	Friday	10:53 am	Government decides to cancel wheat export duty
23.05.15*	Saturday	4:21 pm	Russia may introduce new wheat export duty starting August - source
26.05.15	Tuesday	3:39 pm	Agriculture Ministry approves new formula for grain export duty
29.05.15	Friday	1:48 pm	Russia to introduce new duty on wheat exports on July 1
05.06.15	Friday	3:09 pm	Government not planning for now to change duty on wheat exports, will monitor situation - Dvorkovich
19.06.15	Friday	11:14 am	Grain duty is temporary, needed measure – Dvorkovich
03.08.15	Monday	2:49 pm	Medvedev instructs govt to draft grain export proposals
05.08.15	Wednesday	2:50 pm	Agriculture Ministry favors changes to wheat export duty
11.08.15	Tuesday	5:41 pm	Russian government not intending to limit grain exports, new duty formula is working - Dvorkovich
01.09.15	Tuesday	12:37 pm	Russian govt studying need to change export duty on wheat - Dvorkovich
03.09.15	Thursday	7:00 am	Current grain export duty mechanism justified - agriculture minister
09.09.15	Wednesday	5:28 pm	Russia may lower wheat export duty by increasing deduction term to 6,500 rubles - sources
10.09.15	Thursday	10:37 am	Russian AgMin prepares proposals for change in calculation of export duty for wheat
23.09.15	Wednesday	3:24 pm	Govt commission approves Agriculture Ministry proposal to amend wheat export duty
24.09.15	Thursday	2:36 pm	Govt suggests reducing grain export duty on Oct 1 - Dvorkovich
07.12.15	Monday	4:15 pm	AgMin not expecting end of validity of export duty on wheat for now
21.12.15	Monday	2:19 pm	Agriculture Ministry suggests reducing or zeroing out wheat export duty
13.01.16	Wednesday	12:04 pm	AgMin to submit wheat export duty proposals to govt at end-Jan

to be continued

Date	Weekday	Moscow Time	Title
25.01.16	Monday	9:29 am	Russian ministry mulls tightening grain export restrictions
29.01.16	Friday	3:16 am	No decision on wheat export duty at government meeting - Dvorkovich representative
08.02.16	Monday	1:49 pm	AgMin says expecting wheat duty decision 'hourly'
11.02.16	Thursday	5:41 pm	Russian AgMin suggests keeping wheat duty as tool for regulating market, bringing it close to zero
19.02.16	Friday	9:38 pm	No new decisions on export duty - Econ Ministry
24.02.16	Wednesday	12:21 pm	Russia could scrap export duty on high-protein wheat - Grain Union
29.02.16	Monday	12:31 pm	AgMin sees no grounds yet to review wheat export duty - Tkachev
03.03.16	Thursday	8:02 pm	AgMin won't raise issue of wheat export duty earlier than June
13.04.16	Wednesday	1:02 pm	Export duty on wheat to be in place until at least new harvest - Tkachev
28.04.16	Thursday	3:23 pm	Tkachev says no grounds for canceling wheat export duty; measure justified
26.05.16	Thursday	9:14 am	Russian Agriculture Ministry ready to lift wheat export duty, but sees no need
07.06.16	Tuesday	3:14 pm	Russian AgMin to discuss export duty on wheat in middle of June
09.06.16	Thursday	12:17 pm	Wheat export duty to depend on harvest, grain price – Tkachev
06.07.16	Wednesday	4:55 pm	AgMin to consider lifting export duty on wheat by autumn - Tkachev
19.08.16	Friday	11:26 am	Agriculture Ministry proposes zeroing out wheat export duty until July 1, 2017
22.08.16	Monday	3:31 pm	Econ Ministry backs zeroing of wheat export duty
30.08.16	Tuesday	4:48 pm	AgMin's proposal on nullifying export duty on wheat was supported - sources
31.08.16	Wednesday	6:04 pm	Russian AgMin suggests zeroing wheat export duty from Sept 15
02.09.16	Friday	5:37 pm	Russia govt has decided to set zero wheat export duty - Medvedev

Date	Weekday	Moscow Time	Title
20.09.16	Tuesday	3:57 pm	Wheat export duty may be set to zero from September 23 - sources
22.09.16	Thursday	08:07 pm	Russia nullifies export wheat duty on Sept 22 - Tkachev
30.09.16	Friday	5:03 pm	Restrictions of grain exports only possible due to force majeure - Tkachev
03.10.16	Monday	10:50 am	Dvorkovich: wheat export duty effectively set to zero for indefinite period
18.11.16	Friday	3:07 pm	Russia has no plans to return to wheat export duty - Dvorkovich
21.11.16	Monday	2:55 pm	Grain market regulation for exporters still unpredictable - experts
07.09.17	Thursday	1:19 pm	Russian AgMin submitted proposal to scrap grain export duty a month ago - Grain Union
06.10.17	Friday	11:55 am	Russian Agriculture Ministry asks govt to eliminate grain export duty
28.03.18	Wednesday	1:08 pm	Zero export duty on wheat to be extended beyond July 1 or scrapped - Tkachev
03.04.18	Tuesday	1:54 pm	Dvorkovich: wheat export duty won't increase after July 1
12.04.18	Thursday	3:53 pm	Zero duty on wheat exports to be extended – Dvorkovich
24.05.18	Thursday	6:23 pm	Russia could extend zero wheat export duty by a year to July 1, 2019
26.06.18	Tuesday	1:19 pm	Decision on continuation of zero export duties on wheat essentially adopted for another year - Gordeyev
17.08.18	Friday	4:03 pm	AgMin expects Russia to maintain top spot in wheat exports; regions ask about export restrictions
03.09.18*	Monday	6:36 pm	AgMin, grain exporters to continue monitoring supplies, no grounds yet for their limitation - source
06.09.18	Thursday	3:19 pm	Russian AgMin not planning to introduce export duties on wheat - department chief
21.12.18	Friday	4:13 pm	Russian grain export restrictions not discussed at meeting with exporters - source
16.01.19	Wednesday	5:56 pm	Russian AgMin not mulling grain export restrictions, still forecasting 42 mln tonnes for year

to be continued

Date	Weekday	Moscow Time	Title
27.02.19	Wednesday	11:05 am	Russian Agriculture Ministry imposes tacit quotas on grain exports - paper
27.02.19	Wednesday	12:18 pm	Russia AgMin denies reports on imposition of grain export quotas
08.05.19	Wednesday	4:24 pm	Agriculture Ministry proposes extending zero duty on wheat exports
07.06.19	Friday	12:48 pm	Russian AgMin sees no reasons to maintain export duty on wheat
13.12.19	Friday	10:25 am	Russian AgMin working out mechanism to curb grain exports given "certain" circumstances - minister
14.01.20	Tuesday	3:55 pm	Russian AgMin plans to limit grain exports in H1 2020 to 20 mln tonnes
29.01.20	Wednesday	2:38 pm	Russian AgMin planning to set grain export quota for every farming year
12.03.20	Thursday	2:10 pm	Cancellation of zero export duty for Russian wheat not being discussed - AgMin head
17.03.20	Tuesday	7:00 pm	Russia ready to restrict export of essential goods but this is not currently an issue - Belousov
23.03.20	Monday	7:10 pm	Rosselkhoznadzor bans exports of cereal from Russia until further notice for 10 days effective March 20
24.03.20	Tuesday	5:57 pm	Rosselkhoznadzor lifts temporary ban on export of cereals from Russia - source
27.03.20	Friday	3:55 pm	AgMin proposes quota for Russian grain exports in amount of 7 mln tonnes for April 1-June 30 period
30.03.20	Monday	2:13 pm	Econ Ministry agrees on draft resolution to introduce quotas on Russian grain exports
02.04.20	Thursday	7:10 pm	Russian government decides to institute export quotas on Russian grain through June 30 - resolution
17.04.20	Friday	3:17 pm	AgMin sees no need for export duty on wheat at this time - deputy agriculture minister
20.04.20	Monday	11:19 am	Russia to halt grain exports until June 30 after quota of 7 mln t used up - ministry
26.04.20*	Sunday	5:35 pm	Federal Customs Service stops issuing new declarations for grain export from Russia upon quota's depletion - Ministry of Agriculture

Date	Weekday	Moscow Time	Title
27.04.20	Monday	4:08 pm	Russian MinFin sees no need for export duties on grain, mineral fertilizer - source
29.05.20	Friday	3:32 pm	AgMin proposing that calculation of grain export quota drawdown be changed
30.06.20	Tuesday	4:52 pm	Russia could waive grain export quota at harvest of 125 mln tonnes - newspaper
07.07.20	Tuesday	5:59 pm	Medvedev: tighter control needed over export of Russian agricultural products, grain in particular, to neighboring countries
29.09.20	Tuesday	11:07 am	Russia's Agriculture Ministry sees grain export quotas as relevant even with good harvest
07.10.20	Wednesday	1:53 pm	AgMin plans to impose quota on Russian grain exports for Jan-June 2021
26.10.20	Monday	10:40 am	Ministry expects grain export quota to stabilize prices on Russian market

Note: Days when the CBoT is closed are indicated by *. Time difference between Moscow and Chicago is nine hours.

Source: Own illustration based on Nexis Uni (2020)

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ISSN 1436-221X
ISBN 978-3-95992-152-7

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