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Determinants of spatial market efficiency of grain markets in Russia

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ABSTRACT

Results of an unobserved effects model on the determinants of inter- and intraregional grain market integration in Russia in comparison to the USA highlights the differences of the mechanisms underlying market integration in each market. Physical trade flows are exclusively dominant in Russia; in contrast, in the United States, additional information flows induced by commodity futures markets play a great role. Policies which improve grain market efficiency in Russia should not only foster investments in transportation and trade infrastructure, but also the development of market information services and commodity futures markets.

1. Introduction

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

It can be expected that Russia's wheat production will further increase because of technological progress and recultivating former agricultural land that was abandoned during the Russian transformation process of the early 90s following the decline of the Soviet Union (Fellmann et al., 2014; Lioubimtseva and Henebry, 2012; Schierhorn et al., 2014; Swinnen et al., 2017). Russia has the potential to produce more grain, especially in remote regions. However, this additional wheat production potential not only has to be mobilized, but it also has to be transformed into even more export potential to further increase Russia's role in global wheat exports and, hence, global food security. This requires a spatially efficient domestic grain market that ensures comprehensive and quick transmission of price changes from the grain exporting to the grain producing regions. Nevertheless, at present, variation in the degree of spatial integration of Russia's regional wheat markets with the world wheat markets is large, ranging between 35% and 67% (Götz et al., 2016). The spatial integration of the regional wheat markets is also very heterogeneous. The wheat exporting region of North Caucasus is only weakly integrated with Russia's other domestic grain producing regions (Svanidze and Götz, 2019). This limits the mobilization of additional grain exports, especially from remote

regions. Elaborating on this scenario further, this paper addresses the following research question: Which factors influence the degree of spatial market integration of regional grain markets in Russia? We aim to shed light on the underlying mechanisms of market integration in Russia and to identify the influencing factors. Based on those results we aim to draw policy conclusions on how the Russian wheat market's functioning could be improved.

Our estimation strategy to assess the influence of factors affecting spatial market efficiency in the Russian wheat market is a two-step procedure, also used by Goodwin and Schroeder (1991), Kouyaté and von Cramon-Taubadel (2016), Mu (2018) and Schroeder (1997). In the first step, we estimate the degree of market integration, followed by the second-stage estimations using bootstrapping techniques to test relationships between the strength of price transmission (estimated at the first stage) and the various factors undermining spatial market integration.

We investigate Russia's wheat market in comparison to the corn market of the USA. In this study, the corn market of the USA serves as an empirical benchmark versus a theory-based benchmark for assessing the efficiency of the Russian wheat market. The US corn market is an established export market, whereas the Russian wheat market is an emerging export market. Similar to wheat in Russia, corn is also mainly produced and consumed domestically and heavily traded within the USA. Furthermore, the grain trade in both countries is characterized by large distances, which is important for the analysis of spatial price relationships. By including the corn market of the USA as a reference, we aim to measure the degree of spatial market efficiency of the Russian wheat market against a grain market that many view as relatively efficient in an empirical context (rather than to judge the efficiency of the Russian wheat markets on theory-based benchmark values). Table 1

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Table 1
Market characteristics of the Russian wheat market and the US corn market.

Characteristics	Russia	USA
Primary grain	Wheat	Corn
Primary use of grain	Human consumption	Feed crop
	Feed crop	Ethanol production
Policy variation	High variation	Low variation
Transportation infrastructure	Adequate road transport	Good road transport
	Poor rail transport	Good rail transport
	Poor barge transport	Good barge transport
Futures market	Low volume futures market	High volume futures market
Market information	Poor availability	Good availability



Fig. 1. Map of Russia's grain producing regions.

summarizes similarities and differences between the grain markets in Russia and the USA (for further details see Section 2).

We conduct the analysis at the interregional (between regions) and intraregional (within regions) levels. The interregional analysis centers upon markets in different grain producing regions with large distances from each other (up to 4000 km), whereas markets within the selected grain producing regions with relatively small distances (up to 1000 km) are the focus of the intraregional analysis.

Our study adds to the strand of literature investigating the determinants of spatial price linkages in agricultural commodity markets. In their meta-analysis, Kouyaté and von Cramon-Taubadel (2016) identify the strong negative influence of distance and international borders on spatial price relationships in cereal markets. Ebata et al. (2017) further show that additional increases in distance and travel time to sales markets significantly reduce the farm gate prices of beans in Nicaragua, thus having a negative welfare effect on smallholder producers. For Russia, Arnade and Osborne (2004) find that the regional agricultural commodity markets are segmented due to inadequate physical infrastructure and institutional problems, rather than regional trade policies. Zant (2018) provides additional evidence on the importance of railway connections between markets for reducing crop price dispersion in Malawi.

Market characteristics other than distance and its associated trade costs can also influence spatial price relationships. Apart from confirming the negative influence of distance on market integration, Goodwin and Schroeder (1991) find prices of regional cattle markets of the USA spatially less dependent if both markets in question are of relatively large volume. In addition, the low effort of cattle slaughter plants in discovering local cattle prices positively influences the integration of US cattle markets (Schroeder, 1997). The causes of incomplete price transmission in Russia may also encompass the government's intervention policy, especially if it is non-transparent (Liefert, 2009). Furthermore, Baffes et al. (2017) show that favorable weather conditions decrease domestic prices in the Tanzanian maize market, whereas unfavorable weather conditions have a reverse effect on prices.

Resulting from high market transparency and liquidity, the importance of commodity futures markets for the efficiency of spot (physical) markets has been confirmed by several studies (Adämmer and Bohl, 2018; Garbade and Silber, 1983; Kofi, 1973; McKenzie and Holt, 2002; Peri et al., 2013; Yang and Leatham, 1999). Farmers benefit from futures markets via hedging price risk that is inherited in agricultural production (Pohn et al., 2014; Glauben et al., 2014). Besides managing price volatility, futures markets are also an instrument for price discovery (Valiante, 2013). Particularly, Carter and Mohapatra (2008) find that futures markets in the USA serve a price discovery function, as they react first to market information, which is subsequently transmitted to prices in physical commodity markets. Similarly, Santos (2002) confirms that futures markets in the USA induce stabilizing effects on physical grain markets. Thus, hedging and price discovery enable farmers to reduce uncertainty about their prices for the

future and improve the planning of their production and investment decisions (Loy, 2002).

The remainder of this paper is structured as follows: In the following section, Russia's wheat market characteristics are discussed and compared to those of the corn market of the USA. The methodological framework and model estimation is addressed in Section 3, while Section 4 discusses data and Section 5 presents our empirical results. Finally, Section 6 discusses our results and provides policy implications based on our findings.

2. Characteristics of the Russian grain market and its comparison to the US corn market

Wheat is the primary grain produced in Russia, constituting 60% of total grain production, while corn is a major crop in the USA representing 80% of total grain production (USDA-WASDE, 2017). Wheat production in Russia is concentrated in a limited, yet spatially protracted area, with six economic regions accounting for more than 95% of total wheat production in Russia (Fig. 1). North Caucasus is the largest wheat producing region (40%), followed by West Siberia, Volga and Black Earth (each with a 15% share), while wheat production in Ural and the Central region constitutes 8% and 7% of total wheat production, respectively (Rosstat, 2018). Similarly, the "corn belt" region mainly dominates corn production in the USA, accounting for nearly 70% of total US corn production and exports (USDA-ERS, 2019; USDA-NASS, 2019). In this study, we consider seven corn belt states: Iowa, Illinois, Nebraska, Kansas, Minnesota, Missouri and South Dakota.

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

The remaining wheat that's not exported to the world market is available on Russia's domestic market, where it is mainly used for human consumption and livestock feed. The concentration of human grain consumption in a few city centers (i.e. Moscow, St. Petersburg) and livestock producing regions (i.e. Central and Black Earth) requires the transportation of large amounts of wheat from production to consumption sites over long distances. In contrast, livestock farms and corn processing facilities, such as ethanol plants, in the USA are concentrated in the main corn production regions (with the exception of California

and Texas), ensuring small transport distances (Haddad et al., 2010).

Depending heavily on external supplies, the Central region with Moscow is the primary wheat deficit region in Russia. In contrast, North Caucasus, which has direct access to the ports of the Black Sea—and thus the world market—almost exclusively supplies wheat to the world market, while its role in domestic trade is rather limited. With its high-capacity sea terminals, North Caucasus also serves as a gate-market for other grain producing regions, particularly Volga and Black Earth, which export 30–40% of their production to the world market and supply the rest to the domestic market. In contrast, Ural and West Siberia export less than 5% of their wheat produced internationally, with the latter being the second largest producer of wheat in Russia, but the most remotely located wheat producing region. Not only are these two regions located far away from the world market, with the distance to the Black Sea ports amounting to 4000 km, but they are also distant from the grain consumption regions within Russia. In particular, Moscow is about 2000–3000 km away.

Wheat production in Russia is strongly influenced by climatic and weather conditions (Götz et al., 2016). Owing to vast distances and varying production conditions, yield variation is high across regions. Relatively high yields might be observed in some regions, but relatively low yields in others at the same time. The variation of wheat production within a single region is also generally high. The Russian grain market has also been faced with high policy variation across time. In the last decade, frequent government interventions have repeatedly restricted grain exports to the world market. For example, an export tax of 40% was implemented during the 2007–08 price peak and wheat exports were completely banned in the 2010–11 drought year. Following a severe currency devaluation, a 15% duty on wheat exports with a minimum levy of 35 Euro/ton was imposed by the Russian government in February of 2015 that lasted until May 15th of the same year. Though corn production is characterized by large regional fluctuations in the USA, unlike Russia, US farmers are not exposed to uncertainty originating from frequent changes to policies that impact them.

Rail and road transport are the primary means of wheat transportation in Russia. River transportation is quite unusual for grain delivery in Russia. In contrast, river barge transport is a common practice for grain transport over long distances in the USA due to the large weight capacity of the barges used and low costs. Most of the exported corn from the USA is delivered to the ports via barges. In Russia, rail transport dominates when the transportation distance exceeds 1000 km, while road transport is preferred for routes up to 500 km. However, transport infrastructure is outdated and insufficient in some regions and differs strongly between regions. For instance, the density of the railway network is highest in the European part of Russia, whereas it is much lower in Ural and West Siberia. Excess crops are often difficult to transport beyond West Siberia, as the only railway track connecting the area to the rest of the country is of low capacity and is shared by many other industries (Scherbanin, 2012). In addition, grain traders regularly complain that the number of grain wagons in peak seasons does not suffice (Gonenko, 2011). Grain transportation tariffs are generally low in Russia (AEGIC, 2016). Nonetheless, overall transport costs are high, largely due to inadequate transport infrastructure and logistics, which negatively influences regional wheat trade volumes within Russia (Renner et al., 2014). In addition to high transportation costs, grain markets in Russia are also characterized by high business and market risk (PWC, 2015). Trade costs are especially high due to the difficulty of enforcing contracts and unforeseen policy interventions for the grain markets (Götz et al., 2013, 2016).

Market transparency of grain markets is generally high in the USA, where large information flows are induced by the heavy engagement of farmers and traders in commodity futures exchanges. US farmers and grain buyers regularly participate in futures markets to hedge price risk and discover market prices (Mattos, 2017). Since commodity futures markets dominate price discovery processes in the USA (McKenzie and Holt, 2002; Peri et al., 2013), spot market participants follow this

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

In addition, many private agricultural organizations provide high-frequency market and price information, which is used by farmers to choose locations and traders to sell their grains (Congressional Research Service, 2006).¹ Further, governmental agencies closely monitor market developments and regularly make market and price data publicly available, which improves price adjustment and also lowers market uncertainty in US crop markets (Adjemian et al., 2018). The US Department of Agriculture also regularly provides daily Gulf of Mexico export bids for various grains delivered to Gulf export elevators. In contrast, we are not aware of any agricultural consultancy organization that provides domestic wheat prices on a daily basis in Russia.² Moreover, the somewhat conventional wisdom that the Chicago Board of Trade (CBOT) futures market is the point of reference for grain markets in the Black Sea region does not hold anymore. As Heigermoser et al. (2019) show, Ruble/USD exchange rates and other domestic drivers, but not CBOT futures prices, determine the wheat price volatility of the Russian export markets.

3. Methodology

We use a two-step procedure to empirically assess the influence of factors affecting spatial market efficiency. In the first step, we follow a pairwise cointegration approach (Engle and Granger, 1987) to estimate the degree of market integration by the value of the long-run price transmission elasticities separately for every marketing year. Retrieved price transmission estimates have a panel data format, which serve as a dependent variable in the second-stage estimations (Goodwin and Schroeder, 1991). In the second step, we follow a panel data approach and estimate the unobserved effects model to test relationships between the strength of price transmission and various factors undermining spatial market integration.

3.1. Measurement of market integration

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

However, agricultural price series are often identified as

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

² The well-known agricultural consultancy organizations APK Inform-Agency (<https://www.apk-inform.com>) and SovEcon (<http://www.sovecon.ru/>) provide domestic wheat prices and market reports for Russia at a weekly frequency only. Another recognized consultancy, IKAR (<http://www.ikar.ru/>), provides grain prices every 10 days and market reports on a monthly basis.

nonstationary processes. Estimating price transmission parameters with such data can produce invalid test statistics (Engle and Granger, 1987; Granger and Newbold, 1974). Therefore, for the estimation of the degree of spatial price transmission, we follow Engle and Granger's (1987) cointegration procedure, which implies that the components of the vector $x_t = \begin{bmatrix} x_{1t} \\ x_{2t} \end{bmatrix}$ are cointegrated of order 1, 1 ($x_t \text{ CI}(1, 1)$) if all components of x_t are $I(1)$ and there exists a vector $\zeta (\neq 0) = \begin{bmatrix} \alpha \\ \beta \end{bmatrix}$ so that $\varepsilon_t = \zeta' x_t I(0)$. The vector $\zeta = \begin{bmatrix} \alpha \\ \beta \end{bmatrix}$ is called the cointegrating vector. Based on this definition, price transmission between two spatially separated markets is represented by the price equilibrium equation

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

where p_{1t} and p_{2t} are $I(1)$ domestic prices (in the natural logarithm) observed in two regional markets m (arbitrarily, $m = 1$ and $m = 2$ in this study) and ε_t represents the stationary disturbance term with the integration order of zero, $I(0)$. Parameter α denotes the intercept and β is the cointegration coefficient, interpreted as the long-run price transmission elasticity, which characterizes the magnitude of transmission of price shocks from one market to another. For example, if the price in one region increases by 10%, then the price in another region will increase by $\beta \times 100\%$. Therefore, the existence of cointegration between two nonstationary price series is a precondition for evaluating spatial price relationships within the Engle and Granger model framework. Furthermore, the cointegration equation, such as Eq. (1), is built on an implicit assumption that trade costs are stationary, ensuring that the long-run price equilibrium can be correctly identified (Fackler and Goodwin, 2001).

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

3.2. Determinants of market integration

3.2.1. Model specification

Fackler and Goodwin (2001) argue that "markets should produce prices that accurately reflect all available information about demand and supply conditions as well as transaction costs" (p. 979). This also implies that market integration is a function of trade costs and supply and demand conditions. Trade costs comprise all kinds of costs involved in trading a good between two regions; for example, transportation and marketing costs, as well as unmeasurable costs, such as search costs and risk premiums, resulting from the risks involved in a trading activity (Barrett, 2001). Supply and demand conditions reflect information on the availability and disappearance of a good in the market. Assuming no changes in the beginning and ending stocks, production and import volumes determine the availability of a good in a market, whereas human consumption, exports, fodder use and industrial use represent demand-side factors. Since Russia and the USA barely import any grain and are the largest grain exporters in the world, we only consider grain exports in the model.

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

$$\hat{\beta}_{it} = \theta_0 + \theta_1 \text{distance}_i + \sum_{m=1}^2 [\theta_{2m} \text{export}_{mit} + \theta_{3m} \text{grain production}_{mit} + \theta_{4m} \text{ethanol}_{mit} + \theta_{5m} \text{hog}_{mit} + \theta_{6m} \text{cattle}_{mit} + \theta_{7m} \text{poultry}_{mit} + \theta_{8m} \text{popul}_{mit}] + \theta_9 \text{North Caucasus}_i + \sum_{t=1}^{T-1} \delta_t \text{year}_t + c_i + \varepsilon_{it} \quad (2)$$

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

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

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

Russia and the USA are both the largest exporters of wheat and corn in the world and some grain is exported internationally (presumably from regions with excess production). We consider the export orientation of a grain production region as a further factor influencing the integration of domestic grain markets. An enhancing effect on market integration is observed when the domestic price in a production region that is involved in international trade contributes to price discovery in other domestic production regions. The explanatory variable export_{mit} measures wheat and corn exports in regional markets m in Russia and the USA. However, export data is only available at the interregional level. For the intraregional level, we replace variable export_{mit} with the indicator variable export_t , which equals 1 if a market pair i is located in a region involved in international grain exporting, and is equal to 0 otherwise. We additionally include the dummy variable North Caucasus_i solely for Russia at the interregional level, as Götz et al. (2016) and Svanidze and Götz (2019) have indicated that price developments in North Caucasus are heavily influenced by the world market price and the region is disintegrated with the Russian domestic wheat market.

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

Instead, we consider supply- and demand-side variables, which determine the likelihood of trade between markets—and, hence, market integration. We consider grain production ($\text{grain production}_{mit}$) as the domestic supply-side driver and livestock and poultry inventories (hog_{mit} , cattle_{mit} and poultry_{mit}), population (popul_{mit}) and ethanol production (ethanol_{mit}) as the domestic demand-side drivers.³ We expect a positive relationship between these domestic drivers and the degree of market integration.

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

3.2.2. Estimation approach

A random effects estimator is applied to the unobserved effects model when the observed explanatory variables (\mathbf{x}_{it}) are not correlated

³ Ethanol production is used just for the USA, as biofuel production is absent in Russia.

with the unobserved effect c_i , and the fixed effects estimator otherwise. We estimate Eq. (2) with a random effects estimator in a feasible generalized least squares (FGLS) framework if $\text{Cov}(x_{it}, c_i) = 0$, for $t = 1, 2, \dots, T$; otherwise, we apply a fixed effects estimation framework and use pooled ordinary least squares (pooled-OLS), allowing c_i to be correlated with explanatory variables.

Since the model's dependent variable represents an estimated parameter rather than an observed variable, the test statistics in the second-stage regression do not have standard distributions (Goodwin and Schroeder, 1991). Furthermore, it is expected that heteroscedasticity will be present in the models, leading to an inconsistent variance estimator and inaccurate test statistics (Lewis and Linzer, 2005). To ensure that the obtained coefficient parameter estimates are efficient in an equation with the heteroscedastic error structure, an alternative estimation strategy—the bootstrapping technique—is undertaken to obtain bootstrapped standard errors instead of asymptotic standard errors (Efron and Tibshirani, 1986).

4. Data

4.1. Price series data

We conduct the price transmission analysis for the wheat market of Russia and the corn market of the USA at two different market levels. The interregional analysis centers upon price relationships *between* different grain production regions when distances are large. In contrast, price relationships *within* two selected grain production regions are the focus of the intraregional analysis. Table 2 provides a detailed description of the price series used in our price transmission analysis and their sources, while selected grain prices are plotted in Fig. 2. We estimate price transmission elasticities separately for every marketing year between July 2010 and June 2016. Price series are trimmed as necessary for each price pair in every marketing year to the period for which they overlap.

For the interregional analysis of the grain markets in Russia, we make use of a unique data set of weekly prices of class three wheat (Ruble/ton) for six economic regions. Correspondingly, we employ weekly corn prices (USD/ton) for 15 federal states in the USA. A detailed description of the geographic boundaries of the markets is given in supplementary material A.

The analysis of Russia's intraregional market integration is based on prices observed within two primary wheat production regions. North Caucasus is the primary grain exporting region with direct access to its ports at the Black Sea, whereas West Siberia is primarily involved in the domestic wheat trade due to its large distances from the world market. We consider four price series available for North Caucasus and six price

series for West Siberia. Likewise, the intraregional analysis for the USA covers Iowa, a leading corn production and export region, and North Carolina, which, similarly to West Siberia in Russia, mainly supplies its excess corn production to the domestic market and is the second largest pork production state in the USA. At the intraregional level, Iowa is represented by price series in eight counties and North Carolina by price series in six counties. In addition, we convert corn prices from a daily to biweekly frequency for the purpose of comparison between Russia and the USA at the intraregional level.

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

Thus, altogether we analyze 15 price pairs for Russia and 54 price pairs for the USA at the interregional level. Similarly, we estimate 21 and 41 pair-wise price relationships at the intraregional level for Russia and the USA, respectively. These price pairs are estimated for every marketing year between 2010 and 2016. We report the mean, standard deviation, and the minimum and maximum price transmission elasticities in our data set for each of the price pairs in Russia and the USA separately at the interregional and intraregional level in supplementary material D.

4.2. Panel data

The price transmission elasticities estimated for each price pair on a yearly basis between 2010 and 2016 provide a measure of market integration and enter the unobserved effects model as a dependent variable. Distribution of the long-run price transmission elasticities is provided in Fig. 3.

The overall distribution of the price transmission elasticities is heavily skewed to the left for Russia and the USA at the interregional level (Fig. 3, panel a). The estimates range between zero and one and the degree of price transmission is higher than 0.6 in the majority of cases. However, the left tail is also wider for Russia, indicating a higher incidence of a lower degree of market integration in Russia compared to the USA. At the intraregional level, the distribution approximates to normal, with parameter estimates centered around 0.6 for Russia and 0.95 for the USA (Fig. 3, panel b). Moreover, price transmission elasticities are more densely consolidated around the mean for the USA, whereas they are more widely dispersed for Russia.

We consider the distance between markets, grain production, export

Table 2
Database of grain price series underlying the price transmission analysis.

Markets	Estimated time period ^a	Price pairs	Time frequency	Source
<i>Interregional analysis</i>				
Russia (6 economic regions)	2010–2016	15	Weekly (52 obs.)	Rus. Gr. Union (2016)
USA (15 federal states) ^b	2010–2016	56	Weekly (52 obs.)	USDA-AMS (2016) ^c
<i>Intraregional analysis</i>				
North Caucasus (4 oblasts) ^c	2010–2016	6	Biweekly (24 obs.)	Min. of Ag. (2016)
West Siberia (6 oblasts) ^d	2010–2016	15	Biweekly (24 obs.)	Min. of Ag. (2016)
Iowa (8 counties)	2010–2016	27	Biweekly (24 obs.)	GeoGrain (2016)
North Carolina (6 counties)	2010–2016	15	Biweekly (24 obs.)	NCSU (2017)

^a Price series are estimated separately for each marketing year.

^b Price series for the federal state of Washington are available for 2010–2012 only.

^c Price series for the Republic of Adygea (one of the federal districts in North Caucasus) are available from July 2013 onwards.

^d Price series for Kemerovo oblast, Novosibirsk oblast and Omsk oblast (these are three federal districts in West Siberia) are available starting September 2012, July 2011 and December 2010, respectively.

^e Data for the federal state of Washington is provided by GeoGrain.

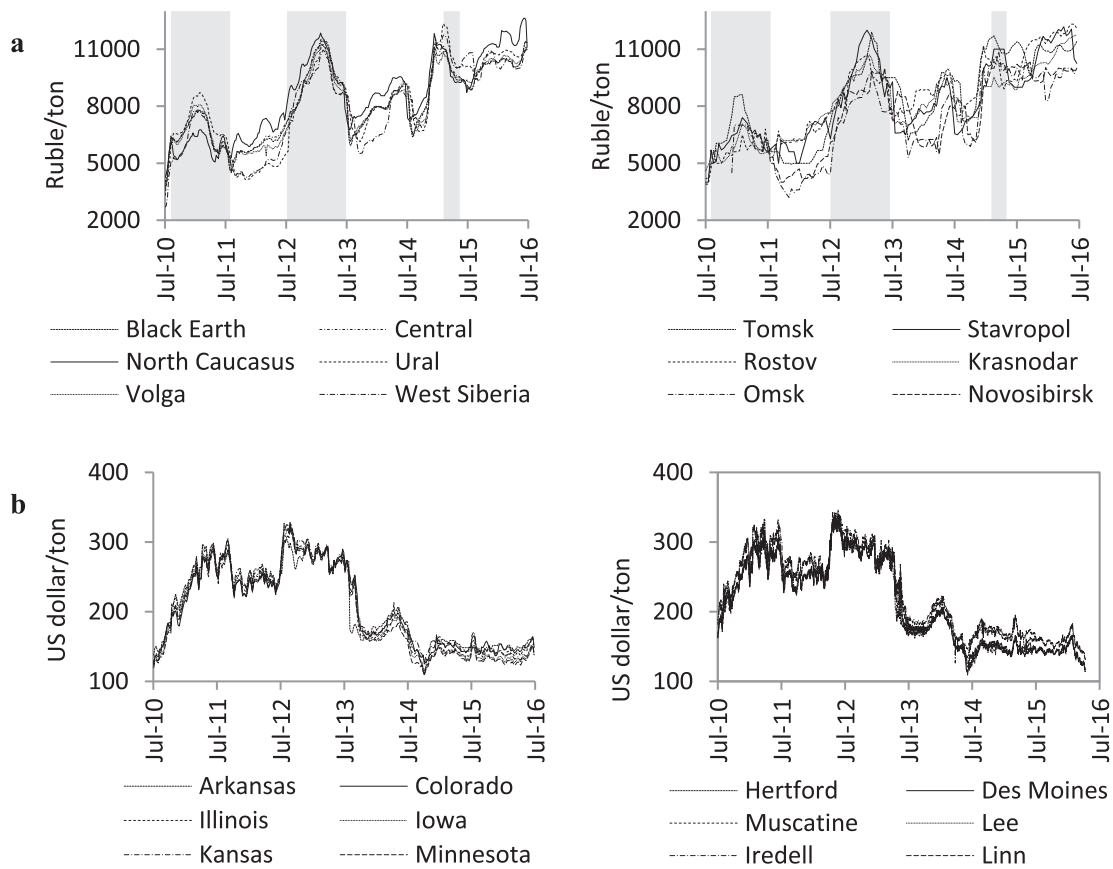


Fig. 2. Development of selected grain prices at the interregional (left) and intraregional (right) levels in (a) Russia and (b) the USA. Note: The bold area on the graph corresponds to the periods of export ban (Aug 2010 - Jul 2011), the draught period (2012–2013), and the export duty (February 2015 - May 2015) imposed in Russia.

volume, ethanol production, cattle, hog, and poultry inventories, along with population, as determinants of the degree of market integration. A detailed description of all variables and their sources is provided in

supplementary material E.1, whereas key descriptive statistics of these variables for interregional and intraregional analysis are summarized in Supplementary material E.2.

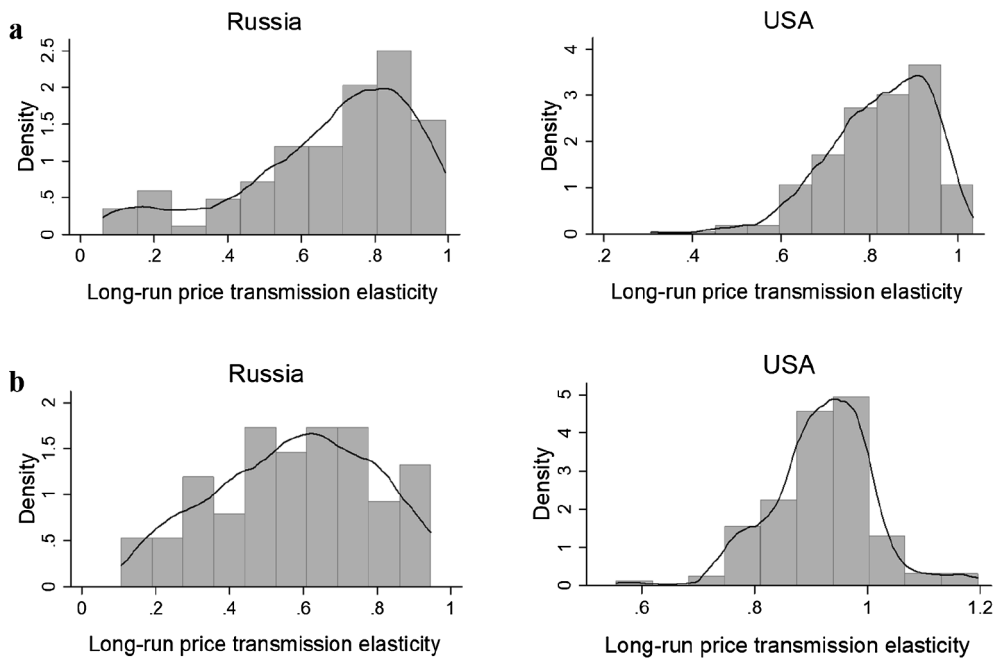


Fig. 3. Distribution of long-run price transmission elasticities: (a) Interregional analysis; (b) Intraregional analysis. Note: The solid line represents the kernel density plot for the distribution of the long-run price transmission elasticities.

5. Empirical results

5.1. Specification and robustness tests

First we check the multicollinearity of the explanatory variables. Pearson's pairwise correlation coefficients, reported in [supplementary material F](#), confirm that grain production and export volume are generally highly correlated in both countries, as are inventories of hog, cattle and poultry. The parameter estimates of these correlated predictors are unlikely to be meaningful. Therefore, to deal with multicollinearity, we estimate two models separately for two sets of explanatory variables with distance being present in both of the model specifications. Model (1) includes distance, export volumes and year-fixed effects, as well as a dummy for the North Caucasus region for Russia at the interregional level. Model (2) contains distance, grain production, hog inventories and year-fixed effects, as well as a dummy for Russia's North Caucasus region at the interregional level. Additionally, for the USA, we include ethanol production to represent demand for corn from the processing industry at the interregional level.⁴

We report bootstrapped parameter estimates of the unobserved effects model to analyze the influence of various market characteristics on market integration at the interregional and intraregional levels in Russia and the USA in [Table 3](#). The bootstrapping estimates were obtained from 10,000 replications. As [Table 3](#) shows, the Hausman specification test ([Hausman, 1978](#)) confirms that the random effects estimator provides efficient and consistent estimates of true parameters for all but two model specifications estimated for the USA at the intraregional level. In addition, autocorrelation is also present in these models based on the Wooldridge's test for autocorrelation. Because of the heteroscedasticity and serial autocorrelation in the model residuals for models (1) and (2) for the USA at the intraregional level, instead of the random effects estimator and bootstrapping regressions, we have used Prais-Winsten generalized least-squares (GLS) estimator ([Prais and Winsten, 1954](#)) with heteroskedastic and contemporaneously correlated disturbances across the panels and AR(1) disturbances within the panels ([Beck and Katz, 1995](#)).

In general, the estimated models fit this data quite well at the interregional level, especially for Russia. On average, 60% and 30% of the variation in price transmission elasticities is explained by the independent variables at the interregional level in the models for Russia and the USA, respectively. We assume that the higher value of the *R*-squared parameter for Russia results from the higher variability of price transmission elasticities, which is caused by higher variation in yields across regions. In addition, many different policy interventions have been observed in the time period underlying this analysis (see [Section 2](#)). However, the *R*-squared is relatively low, averaging approximately 0.2 at the intraregional level for Russia and the USA.⁵

5.2. Determinants of spatial wheat market integration in Russia

[Table 3](#) reports the parameter estimates of the unobserved effects model to analyze the influence of various market characteristics on market integration at the interregional and intraregional levels in Russia and the USA. Results of the analysis at the interregional level indicate a statistically significant negative influence of distance on the

⁴ We intentionally remove the other demand-side explanatory variables: cattle and poultry inventories and population, as they do not yield economically interpretable results (compare [supplementary material G](#)). From the demand-side variables, we just keep hog inventories as they represent the livestock industry and wheat is also heavily used for hog feeding in Russia (as is corn in the USA).

⁵ Especially in the case of the USA, a low *R*-squared might correspond to the high market stability and homogeneity resulting in the generally low variation of the price transmission elasticities.

degree of market integration in both countries; however, the impact is two times higher in Russia compared to the USA. This implies that a *ceteris paribus* increase in distance between markets by 1000 km decreases the long-run price transmission elasticity by 8% in Russia and 4.5% in the USA. In contrast, results at the intraregional level indicate that the influence of distance is, to a large extent, comparable between Russia and the USA. An increase in distance of 1000 km decreases the long-run price transmission elasticity by approximately 12% in Russia and 10–11% in the USA. When assessing the change in coefficient estimates within the countries, the influence of distance increases two times in the USA at the intraregional level compared to the interregional level, whereas this effect is barely differentiated across the level of the analysis for Russia. The difference in the influence of distance on market integration in Russia and the USA at the two levels of market integration analysis provides further evidence of the dissimilarity in the underlying fundamental mechanism of market integration, which we subsequently discuss in depth in the next section.

Our results also identify a positive effect of wheat exports on market integration in Russia at the interregional level. Similarly, the size of corn exports from the largest corn belt exporting states, the corn belt states,⁶ positively influences interregional market integration in the USA according to our model results. However, for Russia, our results indicate that the integration of the largest wheat export region of North Caucasus with Russia's domestic grain markets is 23.2% weaker on average compared to other regions in Russia. At the intraregional level, results indicate that the integration of two markets located in the export region is higher in the USA compared to markets in production regions that are involved in export activities to a low degree. In contrast, this effect does not hold for the Russian wheat markets at the intraregional level.

Coefficient estimates of grain production in model (2) for Russia are not statistically significant at either the interregional nor intraregional level, whereas larger corn production leads to stronger integrated markets in the USA at both levels of the analysis. Further, a larger number of hog inventories implies a stronger transmission of prices between two spatially separated markets in Russia and the USA at the interregional level. This effect does not hold at the intraregional level for Russia and the USA. Additionally, as expected, results show that ethanol production positively influences corn market integration in the USA.

In the next step, we evaluate the parameter estimates of the year dummies for Russia and the USA. The estimated effect suggests an up to three times larger temporal variation in the degree of market integration in Russia compared to the USA at the interregional level. In comparison with the base year of 2011–12 (free trade regime), market integration was 26% higher in 2010–11, when the Russian government completely banned the export of grain, and 31% higher in 2014–15, when the government imposed a wheat export duty. Market integration also increased in 2012–13, when a severe drought caused widespread harvest shortfalls, although wheat exports were not restricted by political market interventions. Not surprisingly, the parameters of year dummies for Russia are less often statistically significant at the intraregional level since the market environment and weather conditions, as well as the policy framework, are more uniform within the production regions. Temporal variation of the price transmission elasticities for the Russian wheat market is relatively lower at the intraregional level compared to the interregional level, albeit still roughly four to five times larger than the parameter estimates obtained for the USA at the intraregional level.

⁶ This corresponds to the variable *export* ($m = 2$), which contains export volumes for seven states: Illinois, Iowa, Kansas, Minnesota, Missouri, Nebraska and South Dakota. Individual price pairs are listed in [Table C.1](#) in [supplementary material C](#).

Table 3

Estimated parameters of the random effects model: interregional and intraregional analysis, Lewis and Linzer procedure.

Explanatory variables	Intraregional analysis				Interregional analysis			
	Russia (1)	Russia (2)	USA (1) [‡]	USA (2) [‡]	Russia (1)	Russia (2)	USA (1)	USA (2)
	Distance	-0.080***	-0.079***	-0.043***	-0.047***	-0.123**	-0.115**	-0.110***
Export (m = 1)	0.010*		0.026					
Export (m = 2)	0.056*		0.005**					
North Caucasus Exporter ^a	-0.232***	-0.085			-0.019		0.052***	
Grain production (m = 1)		-0.002		-0.005		0.001		0.071 [‡]
Grain production (m = 2)		-0.011		0.001***		-0.004		-0.033*
Hogs (m = 1)		0.020		0.029***		-0.299		0.022
Hogs (m = 2)		0.045 [†]		0.001		0.193		0.011
Ethanol (m = 1) ^b				0.008**				
Ethanol (m = 2) ^b				-0.001				
Intercept	0.638***	0.633***	0.828***	0.818***	0.583***	0.602***	0.919***	0.939***
<i>Year dummies: 2011/12 = base year</i>								
2010/11	0.264***	0.149*	0.081***	0.085***	0.159	0.162	0.021***	0.027***
2012/13	0.342***	0.246**	0.075***	0.067***	0.075	0.074	-0.028***	-0.022***
2013/14	0.272***	0.245***	0.083***	0.072***	0.117***	0.170**	-0.029***	-0.031***
2014/15	0.307***	0.305***	-0.025	-0.022	0.061	0.053	0.041***	0.041***
2015/16	-0.030	-0.106	-0.068***	-0.076***	0.019	0.014	-0.023***	-0.026***
N total obs.	90	90	296	296	90	90	252	252
R-squared	0.61	0.61	0.31	0.35	0.17	0.21	0.21	0.21
LR test of heteroscedasticity ^c	105.0 (0.0)	10.1 (0.0)	74.2 (0.03)	87.4 (0.0)	34.2 (0.03)	42.6 (0.0)	80.8 (0.0)	85.8 (0.0)
Wooldridge test for autocorrelation ^c	0.94 (0.35)	1.90 (0.19)	0.02 (0.89)	0.23 (0.63)	1.46 (0.24)	0.63 (0.24)	23.7 (0.0)	23.71 (0.0)
Hausman test: fixed and random effects ^c	1.2 (0.99)	10.4 (0.17)	6.4 (0.49)	8.2 (0.15)	2.2 (0.69)	1.9 (0.99)	80.8 (0.0)	85.8 (0.0)

Note: Model (1) includes distance, export volumes and year-fixed effects; for Russia only, we additionally include a dummy for the North Caucasus region at the interregional level. Model (2) contains distance, grain production, hog inventories and year-fixed effects; we additionally include a dummy for the North Caucasus region for Russia and ethanol production volumes for the USA at the interregional level. [†]p < 0.15.

[‡] Because of the serial autocorrelation in the model residuals, instead of the random effects estimator we have used Prais–Winsten generalized least-squares (GLS) estimator (Prais and Winsten, 1954) with heteroskedastic and contemporaneously correlated disturbances across the panels and AR(1) disturbances within the panels; autocorrelation coefficient is calculated based on the autocorrelation of residuals (Beck and Katz, 1995).

^a Export quantities are only available at the interregional level; at the intraregional level, we use the indicator variable, which equals 1 if a market pair *i* is located in a region heavily involved in international grain exporting, and is equal to 0 otherwise.

^b Ethanol production quantities are only available at the interregional level.

^c P-values in parentheses. Parameter estimates significant at the 10% level at least are marked in bold.

*** p < 0.01.

** p < 0.05.

* p < 0.10.

[†] p-value equals to 0.21.

[‡] p-value equals to 0.16.

6. Discussion of results and policy implications

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

6.1. Discussion of results

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

integration between Russia and the USA.

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

In Russia, the physical trade of wheat mainly fosters market integration at the interregional level, as wheat is heavily transported not only over small distances, but also over distances of up to 4000 km from production to consumption regions (for example, from West Siberia to the Central region). From this result we could imply that information flows play a rather minor role in the integration of the Russian grain market due to the rudimentary development of the futures markets (FAO, 2011). Also, the availability of market and price information based on market monitoring activities by governmental and private agencies is generally low in Russia. Correspondingly, distance has a strong negative influence on market integration at the interregional and

intraregional levels in Russia.

Unlike Russia, information flows, in addition to physical trade flows, are of primary importance for market integration at the interregional level in the USA. We argue that the efficiency of futures markets and their role in the formation of spot prices explains the relatively small influence of distance on corn market integration in the USA at the interregional level. In contrast, corn is heavily physically traded over small distances within production regions in the USA. This explains the identified high influence of distance on intraregional market integration in the USA. For instance, corn consumption sectors, such as ethanol and livestock, are located around cornfields to ensure the efficient organization of markets via minimal travel distances and operational logistics. In contrast, grain production and consumption areas are separated by relatively large distances in Russia and physical trade occurs over long distances (in addition to short-distance trade within region), which is confirmed by the large influence of distance at the intraregional as well as interregional level in Russia.

Even though wheat exports from Russia's production regions positively influence market integration in general, results of the panel data analysis indicate a negative influence of the largest export region of North Caucasus on interregional market integration in Russia. Results show that North Caucasus, which accounts for almost 80% of exported wheat from Russia, is only weakly integrated with the other domestic grain markets. This finding is in line with the results by Götz et al. (2016), indicating that price developments in North Caucasus are strongly influenced by prices on the world market, and Svanidze and Götz (2019), which find that price developments in North Caucasus are only transmitted to other grain production regions of Russia to a limited extent. In the USA, corn exports generally increase domestic market integration. Particularly, corn exports from the largest corn belt exporting states, which account for roughly 75% of total corn exports, positively influence integration of the U.S. corn markets. This effect also holds for the USA at the intraregional level.

Regarding domestic demand-side variables, we identify a strong positive influence of hog inventories on interregional market integration in Russia. Pork production is a dynamically growing sector in Russia (Götz and Jaghdani, 2017). If pork production continues to expand, market integration might further strengthen between the grain and hog producing regions of Russia. We find a positive influence of hog inventories for the US corn markets at the interregional and intraregional levels, whereas this effect is not identified for wheat markets in Russia at the intraregional level.

Our results also show that the Russian wheat market, in contrast to the US corn market, is characterized by large temporal variations in price transmission elasticities resulting from various governmental policy interventions and weather-related harvest shortfalls. The findings imply that price developments in the wheat markets of Russia are vulnerable to frequently changing governmental policies and weather events. In contrast, a smaller variation in the degree of price co-movement in the USA suggests a higher stability in the US corn markets.

6.2. Policy implications

The research findings of this study offer several policy implications for improving the spatial market integration of wheat markets in Russia aimed at the full mobilization of grain production and export potential especially in remote areas.

As distance influences regional wheat market integration in Russia, substantial investments in the grain market and transportation infrastructure are required to improve the integration of domestic markets. This is especially relevant for the grain markets located in the northern and Siberian parts of Russia that are characterized by inadequate transportation infrastructure and large distances to the world market. In addition, those grain production regions might be positively affected by climate change (warmer and milder climate in winter and rising temperatures in summer), thereby further increasing grain production

potential. In contrast, climate conditions for wheat production will worsen in North Caucasus and the southern part of Russia due to the increased number of high-temperature days and lower levels of precipitation, thereby decreasing their importance in Russia's future grain production potential (Belyaeva and Bokusheva, 2018).

As Rada et al. (2019) indicate, the high agricultural productivity growth observed in the southern part of Russia during the last two decades was mainly driven by public investments in railroads. Nevertheless, the development of transportation and trade infrastructure is not sufficient for improving Russia's wheat market efficiency since, until now, commodity futures markets have only been rudimentarily developed. A more active futures market in Russia, along with more widespread information services, could lead to an improvement in the efficiency of Russia's wheat market. However other constraints, such as imperfect road and rail infrastructure, may limit these potential gains in efficiency.

Alternatively, governments could support the restructuring of the wheat supply chain in marginally located regions. Livestock production could be intensified in the remote grain production regions, which could foster reducing the size of interregional grain transportation in Russia. Instead of transporting large amounts of wheat to the world market, they might export smaller volumes of meat to the world market.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.foodpol.2019.101769>.

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