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On the drivers of global grain price volatility: an empirical investigation

Fabio Gaetano Santeramo, Emilia Lamonaca*

University of Foggia, Foggia, Italy

**Corresponding author: fabio.santeramo@unifg.it*

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Abstract: Several drivers may generate market instability, but the partial contribution of different factors is still debated. We investigate how market-based drivers influence the global price volatility of three major grains: wheat, corn, barley. We adopt a Seemingly Unrelated Regression Equations model, in order to investigate potential common patterns. We compare inter-annual, intra-annual, and global volatility, to conclude on short-run and long-run dynamics of markets instability. We quantify the negative relationship linking (temporal) arbitrage and grain price volatility and conclude on the effects of supply movements on price volatility.

Keywords: arbitrage; grain market; price dynamics; Seemingly Unrelated Regression Equations (SURE); shocks

Price volatility may induce instability in agricultural markets and cause serious uncertainty among stakeholders (Acosta et al. 2014; Brümmer et al. 2016). The growing volatility of prices has boosted the general atmosphere of uncertainty in agricultural markets, causing adverse effects (e.g. food emergency, political crisis, poverty, unbalanced conditions) (Wright 2011). Quantifying the effect of specific drivers on price volatility is an issue that merits deeper investigations: do they limit or amplify price volatility?

The literature on dynamics and causes of price volatility in agricultural markets is large: Headey and Fan (2008) analyse the causes of price volatility from a theoretical point of view; Assefa et al. (2015) revise the literature on price volatility transmission. Baffes and Haniotis (2016) suggest that the most influential factors of volatility are the level of stocks and the trend in oil prices and exchange rates; Tadesse et al. (2014) explore the quantitative importance of demand and supply shocks for price volatility, highlighting the amplifier effects of energy and financial markets; Brümmer et al. (2016) examine the effect of exogenous determinants (oil price, exchange rates, weather shocks), concluding that volatility drivers are market specific. Several studies pay attention to the theory of competitive storage: in particular, Cafiero et al. (2011), Bobenrieth et al. (2013), and Cafiero et al. (2015) conclude that stock data are valid indicators of vulnerability to shortages and price spikes; Mitra and Boussard (2012) argue that storage contributes to price volatility; Serra and Gil (2012) suggest that stock buildings reduce price fluctuations.

Numerous studies investigate the role of export restrictions (Martin and Anderson 2011; Anderson 2012; Anderson and Nelgen 2012; Gouel 2013, 2016; Ivanic and Martin 2014; Rude and An 2015; Pieters and Swinnen 2016; Santeramo and Lamonaca 2019) and conclude that trade policies intended to reduce exports increase domestic and global price volatility. A major role is played by production levels. Goodwin et al. (2012) suggest that yield responds to significant price changes occurring in the early growing season. Haile et al. (2014, 2015, 2016) argue that price volatility disincentivizes acreage allocation and yield response.

We distinguish the drivers of price volatility in market based drivers and external shocks. Market based drivers are generated by demand or supply shocks (via levels of domestic consumption and production),

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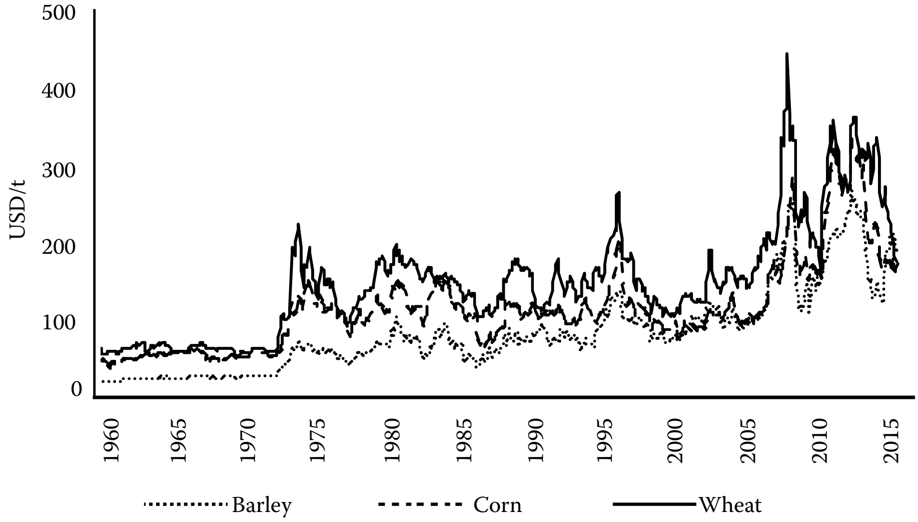

Figure 1. World prices of major grain from crop year 1960 to 2015
Source: authors' elaboration on IMF database (IMF 2016)

or by spatial and temporal arbitrage (via trade and storage) (Santeramo et al. 2018). Examples of external shocks may be the dynamics of real and financial markets (e.g. trend in oil prices and exchange rates), the consequences of unforeseen natural events, and the influence of policy intervention (Tadesse et al. 2014). Interactions among market based drivers and external shocks may exist, and determine different effects on price volatility within a year (inter-annual volatility) or across years (intra-annual volatility). We focus on market based drivers in order to investigate the contribution of spatial and temporal arbitrage and supply and demand shocks on price volatility in the grain market. We expand the analysis of Ott (2014) in particular, following the recommendations of Brümmer et al. (2016), we focus on market-specific determinants of price volatility. While Ott (2014) focuses on the cereal sector as a whole, we derive commodity-specific conclusions for wheat, corn and barley. We analyse global and country-level information from 1960 to 2015 through a Seemingly Unrelated Regression Equations (SURE) model.

We compare inter-annual, intra-annual, and global volatility in order to conclude on the effects of drivers on short-run and long-run dynamics of markets instability. Our novel measure of global volatility captures the overall effect of each driver on global volatility.

ON GRAIN MARKET FUNDAMENTALS

International grain market is characterised by a high concentration of production, trade, and consumption in few countries: it is not a perfectly competitive market. This feature increases the vulnerability to price volatility and food insecurity (Tadesse et al. 2014). Because grain markets are thin, even tiny changes in domestic markets may generate great international impacts and increase global instability: the time series of prices reveal several spikes (Figure 1, Table 1).

Volume of agri-food trade is massive, with a vast portion of demand from emerging economies. Despite significant declines, prices are still higher than pre-financial crisis levels and characterised by remarkable

Table 1. Descriptive statistics for price level and volatility of major grain

	Barley		Corn		Wheat	
	level	volatility	level	volatility	level	volatility
Minimum	19.20	0.001	38.00	0.003	52.18	0.005
Maximum	265.69	0.12	333.05	0.09	439.72	0.12
Median	71.70	0.06	106.30	0.05	142.94	0.05
Mean	81.85	0.06	113.88	0.05	147.78	0.05
Standard deviation	53.89	0.03	58.08	0.02	72.99	0.02

Source: authors' elaboration

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volatility (IMF 2016). It is still unclear what is likely to have caused volatility. Storage is an effective tool to achieve price stabilisation (Bobenrieth et al. 2013), as described by the competitive storage theory (Wright and Williams 1982, 1984; Williams and Wright 1991; Deaton and Laroque 1992; Bobenrieth et al. 2013). Differently, agricultural trade policies, aiming at stabilising price fluctuations and avoiding price spikes, may cause supply shocks, and amplify price volatility (Martin and Anderson 2011; Anderson 2012; Anderson and Nelgen 2012; Ivanic and Martin 2014; Santeramo and Searle 2019).

On the demand and supply sides, crop yields determine production levels and are influenced by external drivers (e.g. weather conditions, pest infestations, environmental conditions and technological changes) (Fisher et al. 2012; Goodwin et al. 2012; Haile et al. 2014). Yield shocks and harvest deficiencies may contribute to global price instability (Fisher et al. 2012; Goodwin et al. 2012; Haile et al. 2014, 2015).

METHODOLOGICAL FRAMEWORK

Data

We analyse global and country-level information, from 1960 to 2015, for three commodities: wheat, corn, and barley (Table 2).

We use monthly prices (USD/t) to compute the measures of price volatility (*cfr.* chapter Volatility Measurement).

The annual data of fundamentals of grain markets are collected from the United States Department of Agriculture's Foreign Agricultural Service, Production, Supply, and Distribution Online (USDA 2016): harvested area (1 000 t) proxies planted area and, jointly with yield (t/ha), indicates the levels of production; domestic consumption (1 000 t) refers to food, seed, industrial, feed and waste consumption; exports (1 000 t) proxy spatial arbitrage; ending stocks (1 000 t) informs on storage levels at the end of marketing year. The marketing year ends in May for wheat and barley, and in August for corn.

We include four control variables: the price of crude oil (USD/barrel), the foreign exchange rates, to proxy of financial economy (U.S. Dollar (USD) against Australian Dollar (AUD), and Chinese Yuan (CNY) against U.S. Dollar), the trade reduction index (which proxy the global impact of policy intervention), and data on natural disasters (1 000 USD) which proxy of exogenous and unforeseen events (Table 3).

Volatility measurement

Price volatility (i.e. price dispersion around a central trend) indicates how much and how quickly prices change over time (Tadesse et al. 2014).

We distinguish inter-annual and intra-annual volatility of price. Inter-annual volatility is the price dispersion across crop years: it influences decisions on long term investments of farmers, storers, and traders. We measure inter-annual volatility as standard deviation $\left(\sigma_y^{y,i}\right)$ of the logarithmic changes of annual prices with respect to a five-years average:

$$\sigma_y^{y,i} = \sqrt{\left(\Delta P_y^{y,i} - \Delta_5 P_y^{y,i}\right)^2} \tag{1}$$

where y indexes year, $\Delta P_y^{y,i} = \ln\left(\frac{P_y^{y,i}}{P_{y-1}^{y,i}}\right)$ is the year-by-year variance, computed on average annual prices of commodity i, and $\left(\Delta_5 P_y^{y,i} = \frac{1}{5}\ln\left(\frac{P_{y+2}^{y,i}}{P_{y-2}^{y,i}}\right)\right)$ is the proportional annual change in prices of commodity i, computed on a five years moving average.

Intra-annual volatility proxies the price dispersion within the crop year: it affects planting decisions. In line with Ott (2014), we measure intra-annual volatility as the standard deviation $\left(\sigma_m^{y,i}\right)$ of the logarithmic changes of monthly price with respect to a thirty-six months monthly price average:

$$\sigma_m^{y,i} = \sqrt{\frac{1}{10}\sum_{m=2}^{12}\left(\ln\left(P_m^{y,i}\Big/P_{m-1}^{y,i}\right) - \mu_y^{y,i}\right)^2} \tag{2}$$

where $P_m^{y,i}$ is the price of commodity i in month m of crop year y and $\mu_y^{y,i} = \frac{1}{11}\ln\left(\frac{P_{12}^{y,i}}{P_1^{y,i}}\right)$ is the proportional monthly change in prices of commodity i, computed as a moving average (η) on twelve months.

We measure global volatility as standard deviation $\left(\sigma_m^{3y,i}\right)$ of the logarithmic changes in monthly price with respect to commodity i from a central trend, computed using a moving average on 36 months:

$$\sigma_m^{3y,i} = \sqrt{\frac{1}{34}\sum_{m=2}^{36}\left(\ln\left(P_m^{y,i}\Big/P_{m-1}^{y,i}\right) - \mu_y^{3y,i}\right)^2} \tag{3}$$

where $\mu_y^{3y,i} = \frac{1}{35}\ln\left(\frac{P_{36}^{y,i}}{P_1^{y,i}}\right)$ is the proportional monthly

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Table 2. Sources of data

Series		Description	Sample	Frequency	Unit	Source
Nominal price by commodity						
Grains	barley	barley (US) feed, No. 2, spot, 20 days to-arrive, delivered Minneapolis from May 2012 onwards; during 1980–2012 April Canadian, feed, Western No. 1, Winnipeg Commodity Exchange, spot, wholesale farmers' price	1960–2015	month	USD/t	World Bank (Pink Sheet) (2016)
				year	USD/t	
	corn	maize (US), No. 2, yellow, f.o.b. US Gulf ports	1960–2015	month	USD/t	
				year	USD/t	
	wheat	wheat (US), No. 1, hard red winter, ordinary protein, export price delivered at the US Gulf port for prompt or 30 days shipment	1960–2015	month	USD/t	
				year	USD/t	
Energy	crude oil	crude oil, average spot price of Brent, Dubai and West Texas Intermediate, equally weighed	1960–2015	month	USD/barrel	
Market fundamentals by commodity (for barley, corn, rice and wheat)						
Grains		annual beginning stock	1960–2015	annual crop	1 000 t	USDA (2016)
		annual ending stock	1960–2015	annual crop	1 000 t	
		annual export	1960–2015	annual crop	1 000 t	
		annual import	1960–2015	annual crop	1 000 t	
		annual production	1960–2015	annual crop	1 000 t	
		annual area harvested	1960–2015	annual crop	1 000 t	
		annual yield	1960–2015	annual crop	t/ha	
		annual domestic consumption (food, seed, industrial, feed and waste consumption)	1960–2015	annual crop	1 000 t	
Common series and macro variables						
Exchange rates		China/U.S. foreign exchange rate	1981–2015	month	–	Federal Reserve Bank (2016)
		U.S./Australia foreign exchange rate	1971–2015	month	–	
TRI		trade reduction index (*TRI*), commodity-specific, all covered tradable products (for barley, corn, rice and wheat)	1960–2011	year	%	Anderson and Nelgen (2013) dataset
Disasters		natural disasters (world total)	1960–2015	year	1 000 USD	EM-DAT (2016)

Source: authors' elaboration

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change in prices of commodity *i*, computed on a three years moving average.

The indicators are computed on grain prices, crude oil price and exchange rates.

Model specification

We suppose that volatility (σ) is a function of market-based variables and of external shocks:

$$\sigma = f\,(\textit{market based drivers, external drivers}) \qquad (4)$$

We use commodity-specific variables: storage levels, trade flows, harvested area, yield, and domestic consumption. The external drivers are common across commodities: price volatility of energy commodities (crude oil) as proxy of real economy; volatility of exchange rates (U.S. Dollar/Australian Dollar, Chinese Yuan/U.S. Dollar) as proxy of financial economy; the trade reduction index (*TRI*) as proxy of policy intervention; natural disasters as proxy of unpredictable and exogenous events.

We estimate a SURE system in order to control for common dynamics. Although there are no explicit relationships among single equations, cross-equations relationships are likely to occur, due to the correlation among simultaneous error terms (Zellner 1962). The estimation of a system of equations improves the estimation. Assuming that cross-equations covariance is constant, the most asymptotically efficient, linear, and unbiased (and efficient) estimator is the Generalized Least Squares (GLS).

Equations 5–7 express, in matrix form, the SURE model, respectively, for inter-annual, intra-annual, and global volatility.
Where *B*, *C*, and *W* indicate barley, corn, and wheat; *y* stands for year, *m* for a month, and *3y* for a time span

Table 3. Descriptive statistics for explanatory variables

Variables		Measure units	Min	Max	Mean	Standard deviation
Barley	ending stock	mln 1 000 t	106.00	374.00	238.00	65.30
	exports	mln 1 000 t	52.00	278.00	145.00	50.20
	harvested area	mln 1 000 t	472.00	840.00	659.00	110.00
	yield	mln t/ha	0.64	1.61	1.42	0.33
	domestic consumption	mln 1 000 t	764.00	1 740.00	1 400.00	251.00
Corn	ending stock	mln 1 000 t	337.00	2 050.00	1 140.00	521.00
	exports	mln 1 000 t	140.00	1 310.00	636.00	269.00
	harvested area	mln 1 000 t	1 020.00	1 810.00	1 330.00	204.00
	yield	mln t/ha	1.15	3.70	2.43	0.81
	domestic consumption	mln 1 000 t	1 940.00	3 880.00	4 970.00	2 170.00
Wheat	ending stock	mln 1 000 t	607.00	2 100.00	1 410.00	451.00
	exports	mln 1 000 t	439.00	1 660.00	948.00	316.00
	harvested area	mln 1 000 t	2 020.00	2 390.00	2 200.00	84.20
	yield	mln t/ha	0.74	2.27	1.56	0.48
	domestic consumption	mln 1 000 t	2 290.00	7 130.00	4 820.00	1 420.00
Oil price		USD/barrel	1.21	132.83	28.18	29.85
USD/AUD[a]		–	0.50	1.49	0.88	0.23
CNY/USD[b]		–	1.55	8.73	6.12	2.22
Natural disasters		mln 1 000 USD	0.48	344.00	48.80	65.70
TRI[c]	barley	–	–0.28	1.09	0.18	0.26
	corn	–	–0.06	0.21	0.05	0.07
	rice	–	0.03	1.23	0.45	0.19
	wheat	–	–0.24	0.53	0.10	0.15

[a]USD/AUD – the exchange rate between U.S. Dollar and Australian Dollar; [b]CNY/USD – the exchange rate between Chinese Yuan and U.S. Dollar; [c]*TRI* – trade reduction index

Source: authors' elaboration

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of 36 months. The left hand side (LHS) of Equations 5–7 is the vector of inter-annual, intra-annual, and global volatilities of grain price: the elements of the vector are current volatilities of barley, corn, and wheat, expressed in logarithmic terms. The right side (RHS) of Equations 5–7 includes the matrix of explanatory variables, where *S*, *EX*, *A*, *Y*, *C* indicate for each commodity (*B*, *C*, *W*) the logarithmic form of storage levels, export flows, harvested area, yield, and consumption at current time; σ^{OIL}, $\sigma^{USD/AUD}$, and $\sigma^{CNY/USD}$ are current volatilities of oil price and of exchange rates between U.S. Dollar (USD) and Australian Dollar (AUD), and Chinese Yuan (CNY) and USD; *TRI* is the trade reduction index of the previous period, used as measure of levels of policy intervention[1]; *Z* is the loss in economic terms caused by natural disasters, used to proxy unpredictable events. The RHS also includes the vector of a constant term (α) and parameters of interest, referred to market based drivers (β_i, with $i = 1, \dots, 5$) and to external drivers (γ, δ, η, θ), and the vector of error terms specific

$$\begin{bmatrix} \boldsymbol{\sigma}_y^{y,B} \\ \boldsymbol{\sigma}_y^{y,C} \\ \boldsymbol{\sigma}_y^{y,W} \end{bmatrix} = \begin{bmatrix} 1 & S_y^{y,B} & EX_y^{y,B} & A_y^{y,B} & Y_y^{y,B} & C_y^{y,B} & \sigma_y^{y,OIL} & \sigma_y^{y,USD/AUD} & TRI_{y-1}^{y,B} & Z_y^y \\ 1 & S_y^{y,C} & EX_y^{y,C} & A_y^{y,C} & Y_y^{y,C} & C_y^{y,C} & \sigma_y^{y,OIL} & \sigma_y^{y,CNY/USD} & TRI_{y-1}^{y,C} & Z_y^y \\ 1 & S_y^{y,W} & EX_y^{y,W} & A_y^{y,W} & Y_y^{y,W} & C_y^{y,W} & \sigma_y^{y,OIL} & \sigma_y^{y,CNY/USD} & TRI_{y-1}^{y,W} & Z_y^y \end{bmatrix} \times \begin{bmatrix} \boldsymbol{\alpha} \\ \boldsymbol{\beta}_1 \\ \boldsymbol{\beta}_2 \\ \boldsymbol{\beta}_3 \\ \boldsymbol{\beta}_4 \\ \boldsymbol{\beta}_5 \\ \boldsymbol{\gamma} \\ \boldsymbol{\delta} \\ \boldsymbol{\eta} \\ \boldsymbol{\theta} \end{bmatrix} + \begin{bmatrix} \boldsymbol{\varepsilon}_y^{y,B} \\ \boldsymbol{\varepsilon}_y^{y,C} \\ \boldsymbol{\varepsilon}_y^{y,W} \end{bmatrix} \quad (5)$$

$$\begin{bmatrix} \boldsymbol{\sigma}_m^{y,B} \\ \boldsymbol{\sigma}_m^{y,C} \\ \boldsymbol{\sigma}_m^{y,W} \end{bmatrix} = \begin{bmatrix} 1 & S_m^{y,B} & EX_m^{y,B} & A_m^{y,B} & Y_m^{y,B} & C_m^{y,B} & \sigma_m^{y,OIL} & \sigma_m^{y,USD/AUD} & TRI_{m-12}^{y,B} & Z_m^y \\ 1 & S_m^{y,C} & EX_m^{y,C} & A_m^{y,C} & Y_m^{y,C} & C_m^{y,C} & \sigma_m^{y,OIL} & \sigma_m^{y,CNY/USD} & TRI_{m-12}^{y,C} & Z_m^y \\ 1 & S_m^{y,W} & EX_m^{y,W} & A_m^{y,W} & Y_m^{y,W} & C_m^{y,W} & \sigma_m^{y,OIL} & \sigma_m^{y,CNY/USD} & TRI_{m-12}^{y,W} & Z_m^y \end{bmatrix} \times \begin{bmatrix} \boldsymbol{\alpha} \\ \boldsymbol{\beta}_1 \\ \boldsymbol{\beta}_2 \\ \boldsymbol{\beta}_3 \\ \boldsymbol{\beta}_4 \\ \boldsymbol{\beta}_5 \\ \boldsymbol{\gamma} \\ \boldsymbol{\delta} \\ \boldsymbol{\eta} \\ \boldsymbol{\theta} \end{bmatrix} + \begin{bmatrix} \boldsymbol{\varepsilon}_m^{y,B} \\ \boldsymbol{\varepsilon}_m^{y,C} \\ \boldsymbol{\varepsilon}_m^{y,W} \end{bmatrix} \quad (6)$$

$$\begin{bmatrix} \boldsymbol{\sigma}_m^{3y,B} \\ \boldsymbol{\sigma}_m^{3y,C} \\ \boldsymbol{\sigma}_m^{3y,W} \end{bmatrix} = \begin{bmatrix} 1 & S_m^{y,B} & EX_m^{y,B} & A_m^{y,B} & Y_m^{y,B} & C_m^{y,B} & \sigma_m^{3y,OIL} & \sigma_m^{3y,USD/AUD} & TRI_{m-12}^{y,B} & Z_m^y \\ 1 & S_m^{y,C} & EX_m^{y,C} & A_m^{y,C} & Y_m^{y,C} & C_m^{y,C} & \sigma_m^{3y,OIL} & \sigma_m^{3y,CNY/USD} & TRI_{m-12}^{y,C} & Z_m^y \\ 1 & S_m^{y,W} & EX_m^{y,W} & A_m^{y,W} & Y_m^{y,W} & C_m^{y,W} & \sigma_m^{3y,OIL} & \sigma_m^{3y,CNY/USD} & TRI_{m-12}^{y,W} & Z_m^y \end{bmatrix} \times \begin{bmatrix} \boldsymbol{\alpha} \\ \boldsymbol{\beta}_1 \\ \boldsymbol{\beta}_2 \\ \boldsymbol{\beta}_3 \\ \boldsymbol{\beta}_4 \\ \boldsymbol{\beta}_5 \\ \boldsymbol{\gamma} \\ \boldsymbol{\delta} \\ \boldsymbol{\eta} \\ \boldsymbol{\theta} \end{bmatrix} + \begin{bmatrix} \boldsymbol{\varepsilon}_m^{3y,B} \\ \boldsymbol{\varepsilon}_m^{3y,C} \\ \boldsymbol{\varepsilon}_m^{3y,W} \end{bmatrix} \quad (7)$$

[1]We consider lagged *TRI* for each commodity to avoid endogeneity carried out by the introduction of restrictive trade measures, according to Trefler (1993).

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for each equation of the system, with expected value zero and variance-covariance matrix which is non zero.

In log-log specifications, the parameters β_i, γ, and δ are interpreted as elasticities: for instance, a percentage change in the explanatory variable implies a β percentage change in volatility. The coefficients η and θ express how unitary variation in influence percentage changes in volatility (for instance a unit variation in *TRI* implies a η percent variation in volatility).

RESULTS AND DISCUSSION

Tables 4–6 show results of SURE estimates for inter-annual, intra-annual, and global volatility. The basic specification (A) includes only market based drivers; external drivers are added in the specification to proxy the real economy (B), financial economy (C), and to control for exogenous events (D) and policy interventions (E).

Price volatility is negatively correlated with ending stock, as also found in Serra and Gil (2012), Bobenrieth et al. (2013) and Ott (2014). This is particularly true for wheat: the coefficients estimated for ending stock are negative and statistically significant in all specifications. The stronger effect occurs in intra-annual volatility: a 1% reduction in storage levels increase price volatility of 0.13–0.22% (Table 4). As for inter-annual and global volatilities, a 1% decrease in ending stock volatilities increase price volatility by 0.02% (Tables 5–6). Storage and price volatility of barley are also negatively correlated: a 1% increase in ending stock reduces by 0.02% (in three out of five cases) inter-annual volatility and by 0.01–0.02% the global volatility (Tables 5– 6). The evidence suggests that storage influences price volatility.

We found intra-annual volatility of barley being inversely related to trade flows, while exports are found to be positively correlated with inter-annual and global volatilities of barley, corn, and wheat (Tables 4–6). In particular, a 1% increase in exports increases inter-annual and global volatilities of wheat by 0.02% (Tables 5–6). A plausible explanation is that, as stated by the Law of One Price, price adjustments in the long-run neutralise the buffering effects exerted by exports on price volatility in the short-run. However, the nature of these relationships is not clear understanding and requires further investigation.

As for supply, the proxies of production (i.e. harvested area and yield) are positively correlated with price volatility of grain. This is in contrast with previous evidence (Haile et al.2015). The strongest results are found for wheat: intra-annual volatility increases by 1.47% (0.23%) due to a 1% increase in harvested area (yield) (Table 4). Increase in harvested area is positively correlated with inter-annual and global volatility of wheat (Tables 5–6). As for barley, harvested area and yield are positively correlated as well with inter-annual and global volatilities: a 1% upward variation in production side increases volatilities of barley by 0.06–0.12% (harvested area), or by 0.02–0.05% (yield) (Tables 5–6). For corn, a 1% growth in yield increases global volatility by 0.05% (Table 6); the harvested area is positively correlated with inter-annual volatility and global volatility (Tables 5–6).

As for the drivers of the demand, we found mixed evidence. In few cases we found a positive correlation between domestic consumption and price volatility of grain: we found positive and statistically significant coefficients for intra-annual volatility of barley and wheat (in two out of five cases) and inter-annual volatility of wheat (in two out of five cases) (Tables 4–5). We found an inverse relationship between domestic consumption and intra-annual volatility of corn, and for inter-annual volatility of barley and wheat, as well as for global volatility for all commodities (in 11 out of 15 cases) (Table 6). The take home message is that domestic consumption increases price instability, as argued by Cafiero et al. (2011) and Thompson et al. (2012). Following shocks of demand, grain price volatility decreases because of the rigidity of the demand with respect to the supply (Cafiero et al. 2011; Thompson et al. 2012).

In agreement with several empirical studies that seek to quantify the relationship between grain and energy markets (Serra and Gil 2012; Ott 2014; Tadesse et al. 2014; Baffes and Haniotis 2016; Brümmer et al. 2016), we found a positive correlation between oil price volatility and price volatility of grains: a 1% growth in volatility of oil prices increases the volatility of grains of 0.07–0.35%. We found that increase in exchange rates decreases grain price volatility, as found in Ott (2014), Baffes and Haniotis (2016), and Brümmer et al. (2016).

The correlation between trade flows and trade barriers is negative, possibly because trade restrictions occur exactly when trade is excessively active (Trefler 1993). We found a negative and significant correlation between variables of policy intervention and price volatility of grain.

We found a positive, although small, correlation between price volatility of grains and natural disasters, as also reported in Brümmer et al. (2016). Natural

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Table 4. Seemingly Unrelated Regression Equations (SURE) results for inter-annual volatility

Variables	Market based drivers			External drivers											
	basic (A)			real economy (B)			financial economy (C)			exogenous events (D)			policy intervention (E)		
	barley	corn	wheat	barley	corn	wheat	barley	corn	wheat	barley	corn	wheat	barley	corn	wheat
Ending stock	–0.07	–0.04	–0.13*	–0.06	–0.05	–0.13*	–0.09	–0.16	–0.22***	–0.08	–0.16	–0.22***	–0.08	–0.08	–0.16*
	(0.06)	(0.04)	(0.07)	(0.06)	(0.04)	(0.07)	(0.10)	(0.11)	(0.08)	(0.09)	(0.11)	(0.08)	(0.10)	(0.12)	(0.09)
Exports	–0.06	0.04	–0.13	–0.06	0.03	–0.11	–0.19	0.03	–0.16	–0.22	0.03	–0.17	–0.29*	0.17	–0.21
	(0.06)	(0.08)	(0.10)	(0.06)	(0.08)	(0.10)	(0.16)	(0.20)	(0.13)	(0.15)	(0.19)	(0.13)	(0.17)	(0.23)	(0.16)
Harvested area	–0.21	–0.21	0.13	–0.22	–0.23	0.08	–0.24	0.75	1.32***	–0.13	0.62	1.31***	–0.01	0.47	1.47***
	(0.13)	(0.33)	(0.32)	(0.13)	(0.32)	(0.32)	(0.35)	(0.59)	(0.44)	(0.35)	(0.59)	(0.44)	(0.36)	(0.61)	(0.47)
Yield	0.05	0.23	0.16	0.04	0.21	0.17	–0.05	0.42	0.23*	–0.08	0.35	0.23*	–0.04	0.60	0.11
	(0.09)	(0.20)	(0.13)	(0.09)	(0.20)	(0.13)	(0.15)	(0.34)	(0.12)	(0.15)	(0.34)	(0.12)	(0.16)	(0.41)	(0.16)
Domestic consumption	0.29*	–0.09	0.14	0.30*	–0.06	0.10	0.40	–0.60	0.48*	0.33	–0.62	0.37	0.25	–0.81*	0.60*
	(0.15)	(0.25)	(0.17)	(0.16)	(0.25)	(0.17)	(0.65)	(0.44)	(0.25)	(0.64)	(0.43)	(0.26)	(0.63)	(0.46)	(0.34)
Oil	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
USD/AUD[a]	no	no	no	no	no	no	yes	no	no	yes	no	no	yes	no	no
CNY/USD[b]	no	no	no	no	no	no	no	yes	yes	no	yes	yes	no	yes	yes
Natural disasters	no	no	no	no	no	no	no	no	no	yes	yes	yes	yes	yes	yes
Barley TRI_{t-12}[c]	no	no	no	no	no	no	no	no	no	no	no	no	yes	no	no
Corn TRI_{t-12}[c]	no	no	no	no	no	no	no	no	no	no	no	no	no	yes	no
Wheat TRI_{t-12}[c]	no	no	no	no	no	no	no	no	no	no	no	no	no	no	yes
Constant	–0.16	3.28	–2.65	–0.15	3.57	–1.31	2.57	–5.72	–34.53***	2.68	–1.50	–31.53***	2.36	–2.32	–38.75***
	(1.66)	(4.36)	(6.92)	(1.67)	(4.32)	(6.86)	(6.00)	(6.70)	(11.26)	(5.87)	(7.07)	(11.40)	(6.36)	(7.94)	(12.92)
Observations	52	52	52	52	52	52	31	31	31	31	31	31	30	30	30
R-squared	0.14	0.03	0.06	0.15	0.08	0.11	0.19	0.22	0.49	0.23	0.27	0.51	0.27	0.27	0.52

standard errors are in parentheses; ***, **, and * indicate statistical significance at 1, 5, and 10%; [a]USD/AUD – the exchange rate between U.S. Dollar and Australian Dollar; [b]CNY/USD – the exchange rate between Chinese Yuan and U.S. Dollar; [c]*TRI* – trade reduction index

Source: authors' elaboration

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Table 5. Seemingly Unrelated Regression Equations (SURE) results for intra-annual volatility

Variables	Market based drivers			External drivers											
	basic (A)			real economy (B)			financial economy (C)			exogenous events (D)			policy intervention (E)		
	barley	corn	wheat	barley	corn	wheat	barley	corn	wheat	barley	corn	wheat	barley	corn	wheat
Ending stock	–0.01	0.00	–0.04***	–0.01	0.00	–0.04***	–0.02***	0.00	–0.03***	–0.02***	0.00	–0.03***	–0.02***	0.00	–0.04***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Exports	0.04***	0.03***	–0.01	0.04***	0.02***	0.02*	0.03***	0.02***	0.02**	0.03***	0.02***	0.00	0.03***	0.02***	0.03***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Harvested area	0.06***	–0.01	0.01	0.07***	0.00	–0.02	0.09***	0.00	0.00	0.08***	0.00	0.06**	0.07***	0.04*	–0.02
	(0.01)	(0.02)	(0.03)	(0.01)	(0.02)	(0.03)	(0.01)	(0.02)	(0.02)	(0.01)	(0.02)	(0.02)	(0.01)	(0.02)	(0.02)
Yield	0.02**	0.02	0.01	0.02**	0.01	0.01	0.03***	0.01	0.03***	0.04***	0.00	0.03***	0.03***	–0.01	0.08***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Domestic consumption	0.02	–0.02	0.07***	0.00	–0.02	0.03*	–0.02*	–0.01	0.01	–0.02	–0.01	0.00	–0.01	0.00	–0.06***
	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)	(0.02)	(0.02)	(0.01)
Oil	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
USD/AUD[a]	no	no	no	no	no	no	yes	no	no	yes	no	no	yes	no	no
CNY/USD[b]	no	no	no	no	no	no	no	yes	yes	no	yes	yes	no	yes	yes
Natural disasters	no	no	no	no	no	no	no	no	no	yes	yes	yes	yes	yes	yes
Barley TRI_{t-12}[c]	no	no	no	no	no	no	no	no	no	no	no	no	yes	no	no
Corn TRI_{t-12}[c]	no	no	no	no	no	no	no	no	no	no	no	no	no	yes	no
Wheat TRI_{t-12}[c]	no	no	no	no	no	no	no	no	no	no	no	no	no	no	yes
Constant	–2.46***	–0.15	–0.75	–2.27***	–0.27	0.17	–1.89***	–0.24	–0.22	–1.72***	–0.08	–1.01**	–1.74***	–0.97***	0.70
	(0.15)	(0.27)	(0.58)	(0.15)	(0.27)	(0.54)	(0.14)	(0.28)	(0.52)	(0.14)	(0.30)	(0.51)	(0.16)	(0.35)	(0.50)
Observations	661	661	661	661	661	661	661	661	661	661	661	661	624	624	624
R-squared	0.38	0.20	0.17	0.43	0.32	0.39	0.55	0.31	0.40	0.55	0.32	0.46	0.57	0.35	0.54

standard errors are in parentheses; ***, **, and * indicate statistical significance at 1, 5, and 10%; [a]USD/AUD – the exchange rate between U.S. Dollar and Australian Dollar; [b]CNY/USD – the exchange rate between Chinese Yuan and U.S. Dollar; [c]*TRI* – trade reduction index

Source: authors' elaboration

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Table 6. Seemingly Unrelated Regression Equations (SURE) results for global volatility

Variables	Market based drivers			External drivers											
	basic (A)			real economy (B)			financial economy (C)			exogenous events (D)			policy intervention (E)		
	barley	corn	wheat	barley	corn	wheat	barley	corn	wheat	barley	corn	wheat	barley	corn	wheat
Ending stock	0.00	0.00	−0.03***	−0.01	0.00	−0.01***	−0.01***	0.01***	−0.01***	−0.01***	0.01***	−0.01***	−0.02***	0.00	−0.02***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Exports	0.02***	0.04***	−0.01	0.02***	0.03***	0.02***	0.02***	0.04***	0.02**	0.02***	0.04***	0.00	0.02***	0.03***	0.02***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Harvested area	0.08***	0.02**	0.03	0.08***	0.02*	−0.03	0.12***	0.03**	0.01	0.12***	0.02	0.07***	0.09***	0.08***	−0.01
	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)
Yield	0.05***	0.06***	0.01	0.04***	0.04***	−0.01	0.05***	0.06***	0.04***	0.05***	0.05***	0.03***	0.03***	0.05***	0.08***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Domestic consumption	0.01	−0.07***	0.05***	0.00	−0.05***	0.01	−0.07***	−0.08***	−0.02**	−0.06***	−0.08***	−0.03***	−0.03***	−0.08***	−0.08***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Oil	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
USD/AUD[a]	no	no	no	no	no	no	yes	no	no	yes	no	no	yes	no	no
CNY/USD[b]	no	no	no	no	no	no	no	yes	yes	no	yes	yes	no	yes	yes
Natural disasters	no	no	no	no	no	no	no	no	no	yes	yes	yes	yes	yes	yes
Barley TRI_{t-12}[c]	no	no	no	no	no	no	no	no	no	no	no	no	yes	no	no
Corn TRI_{t-12}[c]	no	no	no	no	no	no	no	no	no	no	no	no	no	yes	no
Wheat TRI_{t-12}[c]	no	no	no	no	no	no	no	no	no	no	no	no	no	no	yes
Constant	−2.72***	−0.45***	−0.98**	−2.38***	−0.35**	0.45	−1.68***	−0.43***	−0.22	−1.78***	−0.20	−1.06***	−1.69***	−1.27***	0.79**
	(0.12)	(0.159)	(0.49)	(0.11)	(0.14)	(0.41)	(0.10)	(0.16)	(0.40)	(0.103)	(0.16)	(0.36)	(0.11)	(0.18)	(0.31)
Observations	637	637	637	637	637	637	637	637	637	637	637	637	601	601	601
R-squared	0.44	0.36	0.13	0.54	0.50	0.51	0.74	0.50	0.52	0.74	0.53	0.61	0.74	0.61	0.77

standard errors are in parentheses; ***, **, and * indicate statistical significance at 1, 5, and 10%; [a]USD/AUD is the exchange rate between U.S. Dollar and Australian Dollar; [b]CNY/USD is the exchange rate between Chinese Yuan and U.S. Dollar; [c]*TRI* – trade reduction index

Source: authors'elaboration

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disasters may be considered as completely exogenous drivers, because they can indiscriminately damage any parts of the world, reducing the capacity of a producer to obtain adequate yields.

CONCLUSION

Price volatility, a typical feature of prices of grain commodity, is driven by several factors. Understanding how the drivers of volatility act may help to define actions to limit the negative consequences of price instability. We analyse market based drivers of price volatility: spatial and temporal arbitrage, and drivers of demand and supply. We focus on three important grains: wheat, corn, and barley.

We confirm previous findings in terms of a negative relationship between arbitrage and grain price volatility: in particular, storage acts as an authentic buffer of volatility in grain market (Guerra et al. 2014; Ott 2014; Tadesse et al. 2014; Clech and Fillat-Castejón 2017). We found that trade flows influence price volatility of grain, as shown by Ivanic and Martin (2014). We also found that demand shocks diminish price volatility, whereas supply shocks exacerbate it. This result, surprisingly in contrast with Haile et al. (2015), may be plausibly explained by the larger rigidity of the demand with respect to the supply (Cafiero et al. 2011; Thompson et al. 2012).

We analysed potential external drivers of volatility related to real and financial economy variables (Zhang et al. 2010; Tadesse et al. 2014; Baffes and Haniotis 2016) as well as to indicators of policy interventions and of exogenous events. We show that energy and financial markets, as well as unpredictable events, tend to have potentially destabilising impacts on prices, whereas policy intervention may buffer instability in grain prices.

Our contribution to the existing debate is at least twofold: firstly, we provide commodity-specific evidence, discriminating short-and long-run dynamics; secondly, we explicitly assess the role of market based and of external drivers of price volatility in the grain market.

REFERENCES

Acosta A., Ihle R., Robles M. (2014): Spatial price transmission of soaring milk prices from global to domestic markets. Agribusiness, 30: 64–73.

Anderson K. (2012): Government trade restrictions and international price volatility. Global Food Security, 1: 157–166.

Anderson K., Nelgen S. (2012): Trade barrier volatility and agricultural price stabilization. World Development, 40: 36–48.

Anderson K., Nelgen S. (2013): Updated National and Global Agricultural Trade and Welfare Reduction Indexes, 1955 to 2011. World Bank, Washington DC, June.

Assefa T.T., Meuwissen M.P., Oude Lansink A.G. (2015): Price volatility transmission in food supply chains: a literature review. Agribusiness, 31: 3–13.

Baffes J., Haniotis T. (2016): What explains agricultural price movements? Journal of Agricultural Economics, 67: 706–721.

Bobenrieth E., Wright B., Zeng D. (2013): Stocks to use ratios and prices as indicators of vulnerability to spikes in global cereal markets. Agricultural Economics, 44: 43–52.

Brümmer B., Korn O., Schlüßler K., Jamali Jaghdani T. (2016): Volatility in oilseeds and vegetable oils markets: Drivers and spillovers. Journal of Agricultural Economics, 67: 685–705.

Cafiero C., Bobenrieth E.S.A., Bobenrieth J.R.A., Wright B.D. (2011): The empirical relevance of the competitive storage model. Journal of Econometrics, 162: 44–54.

Cafiero C., Bobenrieth H.E.S.A., Eugenio S.A., Bobenrieth H., Juan R.A., Wright B.D. (2015): Maximum likelihood estimation of the standard commodity storage model: Evidence from sugar prices. American Journal of Agricultural Economics, 97: 122–136.

Clech N., Fillat Castejón C. (2017): International aggregate agricultural supply for grain and oilseed: The effects of efficiency and technological change. Agribusiness, 33: 569–585.

Deaton A., Laroque G. (1992): On the behaviour of commodity prices. The Review of Economic Studies, 59: 1–23.

EM-DAT (2016): The international disasters database. Centre for Research on the Epidemiology of Disasters – CRED. Brussels, Belgium.

Federal Reserve Bank (2016): Foreign Exchange Rates Data. Board of Governors of the Federal Reserve System, USA.

Fisher A.C., Hanemann W.M., Roberts M.J., Schlenker W. (2012): The economic impacts of climate change: evidence from agricultural output and random fluctuations in weather: comment. The American Economic Review, 102: 3749–3760.

Goodwin B.K., Marra M., Piggott N., Mueller S. (2012): Is yield endogenous to price? An empirical evaluation of inter-and intra-seasonal corn yield response. North Carolina State University.

Gouel C. (2013): Optimal food price stabilisation policy. European Economic Review, 57: 118–134.

Gouel C. (2016): Trade policy coordination and food price volatility. American Journal of Agricultural Economics, 98: 1018–1037.

Guerra V.E.A., Bobenrieth H.E.S.A., Bobenrieth H.J.R.A., Cafiero C. (2014): Empirical commodity storage model: the

https://doi.org/10.17221/76/2018-AGRICECON

challenge of matching data and theory. European Review of Agricultural Economics, 42: 607–623.

Haile M.G., Kalkuhl M., von Braun J. (2014): Inter-and intra-seasonal crop acreage response to international food prices and implications of volatility. Agricultural Economics, 45: 693–710.

Haile M.G., Kalkuhl M., von Braun J. (2015): Worldwide acreage and yield response to international price change and volatility: a dynamic panel data analysis for wheat, rice, corn, and soybeans. American Journal of Agricultural Economics, 98: 172–190.

Haile M.G., Kalkuhl M., von Braun J. (2016): Worldwide acreage and yield response to international price change and volatility: a dynamic panel data analysis for wheat, rice, corn, and soybeans. In: Haile M.G., Kalkuhl M., Von Braun J.: Food Price Volatility and Its Implications for Food Security and Policy. Springer International Publishing: 139–165.

Headey D., Fan S. (2008): Anatomy of a crisis: the causes and consequences of surging food prices. Agricultural Economics, 39: 375–391.

International Monetary Fund (IMF) (2016): International Monetary Fund.

Ivanic M., Martin W. (2014): Implications of domestic price insulation for global food price behavior. Journal of International Money and Finance, 42: 272–288.

Martin W., Anderson K. (2011): Export restrictions and price insulation during commodity price booms. American Journal of Agricultural Economics, 94: 422–427.

Mitra S., Boussard J.M. (2012): A simple model of endogenous agricultural commodity price fluctuations with storage. Agricultural Economics, 43: 1–15.

Ott H. (2014): Volatility in cereal prices: intra-versus inter-annual volatility. Journal of Agricultural Economics, 65: 557–578.

Pieters H., Swinnen J. (2016): Trading-off volatility and distortions? Food policy during price spikes. Food Policy, 61: 27–39.

Rude J., An H. (2015): Explaining grain and oilseed price volatility: The role of export restrictions. Food Policy, 57: 83–92.

Santeramo F.G., Lamonaca E. (2019): The effects of non-tariff measures on agri-food trade: a review and meta-analysis of empirical evidence. Journal of Agricultural Economics (In Press).

Santeramo F.G., Searle S. (2019): Linking soy oil demand from the US Renewable Fuel Standard to palm oil expansion through an analysis on vegetable oil price elasticities. Energy Policy, 127: 19–23 (In Press).

Santeramo F.G., Lamonaca E., Contò F., Stasi A., Nardone G. (2018): Drivers of grain price volatility: a cursory critical review. Agricultural Economics – Czech, 64: 347–356.

Serra T., Gil J.M. (2012): Price volatility in food markets: can stock building mitigate price fluctuations? European Review of Agricultural Economics, 40: 507–528.

Tadesse G., Algieri B., Kalkuhl M., von Braun J. (2014): Drivers and triggers of international food price spikes and volatility. Food Policy, 47: 117–128.

Thompson W., Smith G., Elasri A. (2012): World Wheat Price Volatility: Selected Scenario Analyses. OECD Food, Agriculture and Fisheries Papers No. 59. OECD Publishing.

Trefler D. (1993): Trade liberalization and the theory of endogenous protection: an econometric study of US import policy. Journal of Political Economy, 101: 138–160.

United States Department of Agriculture, Foreign Agricultural Service, Production, Supply and Distribution Online (USDA) (2016): United States Department of Agriculture, Foreign Agricultural Service, Production, Supply and Distribution Online.

Williams J.C., Wright B.D. (1991): Storage and Commodity Markets. Cambridge University Press, Cambridge, England.

World Bank (Pink Sheet) (2016): World Bank Commodities Price Data. World Bank.

Wright B.D. (2011): The economics of grain price volatility. Applied Economic Perspectives and Policy, 33: 32–58.

Wright B.D., Williams J.C. (1982): The economic role of commodity storage. The Economic Journal, 596–614. [Republished in The International Library of Critical Writings in Economics, The Economics of Commodity Markets edited by D. Greenaway and C.W. Morgan. Edward Elgar Publishing Ltd., Cheltenham, UK, 1999.]

Wright B.D., Williams J.C. (1984): The welfare effects of the introduction of storage. The Quarterly Journal of Economics, 99: 169–192.

Zellner A. (1962): An efficient method of estimating seemingly unrelated regressions and tests for aggregation bias. Journal of the American Statistical Association, 57: 348–368.

Zhang Q., Reed M.R., Saghaian S.H. (2010): The impact of multiple volatilities on import demand for US commodities: the case of soybeans. Agribusiness, 26: 202–219.

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