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THE DYNAMICS OF DEPENDENCIES BETWEEN THE WORLD GRAIN AND OILSEED MARKETS

Abstract:

The paper analyses relations between world grain and oilseed markets in the period from the beginning of 2000 to the middle of 2018. The study covered the period of drastic hikes and drops of cereal grain and oilseed prices during the economic and financial crisis. The study assessed the strength and dynamics of dependencies between rates of return from grain and oilseed sub-Indexes of the International Grains Council. For this purpose copula-based multivariate GARCH models were used, and dynamic Kendall's tau coefficients and dynamic tail dependence coefficients were calculated. Among the analysed markets the strongest (weak or moderate) relationships were found between the maize and soybean markets, and between the wheat and maize markets, with the linkages changing in time. The greatest probabilities of extreme events transfer were recorded for the maize and soybean markets.

Keywords:

agricultural raw materials, copula-GARCH model, dynamic dependencies, Kendall's tau coefficient, tail dependence

JEL Classification: C58, Q11, Q13

1 Introduction

It is essential for producers and processors of agricultural raw materials to understand evolutionary trends in prices for agricultural raw materials, since prices provide the only directly observable market parameter affecting the degree of execution of objective functions for these entities (Hamulczuk, Klimkowski, 2011). Production of cereal grains and oilseeds is a major direction in agricultural production worldwide. Information concerning the situation on the world grain and oilseed markets is provided by the International Grains Council Grains and Oilseeds Index (IGC GOI). In the period of 2006 – mid-2008 this index increased by almost 160%, while the wheat sub-Index increased by over 240% (2006 – February 2008), and the sub-Indexes for maize increased by over 190% (2006 – June 2008), soybean – by 140% (2006 – June 2008), barley – by almost 190% (2006 –September 2007) (Fig. 1).

Literature sources present numerous studies explaining the evolution of prices for agricultural raw materials, including drastic increases in prices in the years 2006–2008 (Świerczyńska, 2008; Cooke, Robles, 2009; Gilbert, 2010; Abbott, Borot de Battisti, 2011). The most frequently mentioned aspect is connected with changes in supply and demand factors as a cause for increases in prices for agricultural raw materials. Economic growth in Asian countries, particularly China, is considered to be a key demand factor. The primary supply factors include low levels of raw material stocks[1], undercapitalisation of agriculture, fertiliser price increases and adverse weather conditions[2]. It is also pointed out that trade liberalisation may have also contributed to increased prices for agricultural raw materials[3].

Growing demand for cereal grains and oilseeds for biofuel production is presented as a major factor influencing an increase in prices for these raw materials. Biofuels (ethanol, biodiesel) are typically produced from maize, rapeseed and soybean. The European Union in 2001 and the US Congress in 2005 introduced the obligations to add ethanol to fuels (Świerczyńska, 2008), which increased the use of grains and oilseeds in biofuel production. These changes result in stronger relationships between the prices of grains and oilseeds with oil prices. Conley and George (2008) in their studies indicated the effect of the development of ethanol market on maize prices and due to the rotation in plant production – also on prices of soybean, wheat and cotton. Saghaian (2010) stated that monthly oil prices are strongly correlated with monthly prices for agricultural raw materials, although the direction of the cause and effect dependencies is ambiguous. It was reported in that study that oil prices constituted a Granger causality for prices of

[1] In the USA in February 2008 wheat stocks dropped to the 60-year low (Reguly, 2008).

[2] Due to prolonged drought in 2006 and 2007 in Australia cereal grain exports decreased in relation to the level in 2005 by 9.2 million tonnes, while due to poor harvests the EU and Ukraine reduced exports by 10 million tonnes (Świerczyńska, 2008).

[3] After 2004 in most countries except for the USA and the EU countries subsidies were reduced, while the USA introduced the biofuel subsidy scheme (Reguly, 2008).

maize, soybean and wheat (1996–2009). In turn, Hertel and Beckman (2011) observed that the correlation between monthly oil prices and maize prices varied in the period of 2001 – May 2009, it was weak positive at low oil prices (January 2001 – August 2007), very strong positive at high oil prices (September 2007 – October 2008) and moderate positive at medium prices (November 2007 – May 2009).

Apart from oil prices studies were also conducted on the effect of other factors, i.e. monetary policy primarily of the USA before 2007, financial speculation on prices of agricultural raw materials (Cooke, Robles, 2009; Inamura et al., 2011). In a study (Inamura et al., 2011) an opinion was presented suggesting that a lenient monetary policy stimulates the physical and speculative demand for raw materials. The effect of financial speculation on prices and price risk of agricultural raw materials may be considered ambiguous. In mid-2000's investors increased the shares of raw materials in their portfolios. This resulted from the potential to obtain a comparable rate of return from raw materials to that from stocks, a low or negative correlation of rates of return from commodities and rates of return from conventional assets, thus facilitating better portfolio diversification (Gorton, Rouwenhorst, 2004; Inamura et al., 2011) and providing an inflation hedge (Gorton, Rouwenhorst, 2004). Moreover, new instruments were created for investment in commodities, i.e. commodity indexes and ETFs (Inamura et al., 2011). A rapid increase in activity of financial investors operating on agricultural raw material markets is termed financialisation of these markets. Some researchers have started to interpret increases in prices and price risk of agricultural raw materials accompanying this phenomenon as its consequences (Tomaszewski, 2015). Such observations resulted from e.g. a study by Mayer (2009), who stated that high activity of financial investors on futures markets for maize, soybean and soybean oil was a Granger causality for considerable price swings from the level resulting from the supply and demand equilibrium (January 2006 – June 2009). In turn, Hernandez and Torero (2010) reached a conclusion that rates of return from prices of futures contracts for wheat, maize and soybean were a Granger causality for rates of return from cash prices for respective raw materials. The interdependencies between rates of return from futures prices and cash prices of raw materials have been increasing since mid-2000's. A study by Cooke and Robles (2009) confirmed that speculation on financial markets was a significant Granger causality for the observed increase in prices for wheat, maize, rice and soybean in the years 2006 – mid-2008. However, when the study period was extended to include 2008–2009, i.e. a period of dropping prices for raw materials, it could no longer be inferred that speculation in the financial market was the cause for increased raw material prices. Papers (Zawojska, 2011; Tomaszewski, 2015) presented a list of studies clearly indicating a negative effect of financialisation of agricultural raw material markets on the levels and volatility of their prices as well as studies, in which no such definite hypotheses were formulated and stressing the effect of other factors as well.

The above-mentioned phenomena have also contributed to changes in relationships between prices of agricultural raw materials. Saghaian (2010) indicated a strong positive correlation between monthly prices of wheat, maize and soybean in the period of 1996 – 2009. Results of his analyses did not include changes in temporal dependencies and showed no definite direction of cause and effect relationships, as the results depended on the applied methodology. In turn, Grosche and Heckelei (2016) investigated the effect of transferring price volatility between futures contracts for wheat, soybean and maize in the period from June 1999 to December 2013. For most of that period the volatility was transferred from maize to wheat and soybean, with the direction of price fluctuation transfer between soybean and wheat changing with time. Similar results were obtained for the period 2000–2016 (Śmiech, Papież, Fijorek, 2017). Moreover, analyses were also conducted on the transfer of extreme price risk between contracts for cereals and oilseeds at two exchanges, CBOT and Euronext in Paris in the years 2006–2016 (Just, 2017). That study found Granger causalities in risk between certain contracts. The character of these dependencies was different at the exchanges in Chicago and Paris. Economists agree that grain and oilseed markets are interrelated. Studies concerning these relationships vary in terms of the adopted data selection characteristics (spot prices, futures prices, data frequency), the period covered by analyses and they often disregard variability of correlations in time. The aim of this study is to assess the strength of the dependencies between world grain and oilseed markets and to verify whether the strength of these dependencies is constant in time. For this purpose daily wheat, maize, soybean and barley IGC sub-Indexes for the period of 2000 – June 2018 were used. The dynamics of dependencies between world grain and oilseed markets was modelled by means of the copula-DCC-GARCH or copula-CCC-GARCH models, and the applied measures of the strength of the linkages were dynamic Kendall's tau coefficients and dynamic tail dependence coefficients.

This paper consists of the introduction, three principal parts and the concluding remarks. The first part of the paper presents the applied methods, while the second chapter characterises data used in the analyses. The last chapter presents and describes the results.

2 Methodology

Analysis of the dynamics of dependencies between grain and oilseed markets required the application of the copula-DCC-GARCH model. Multivariate GARCH models make it possible to model conditional correlations changing in time. The Dynamic Conditional Correlation (DCC) models are parsimonious parametric methods modelling conditional correlations, which provide relatively good results (Doman, Doman, 2009). A drawback of the DCC model is connected with the limitations imposed on the multivariate joint distribution defining the structure of dependencies between variables and marginal distributions of these variables. The primary advantage of copulas is connected with the independence of the joint distribution between variables on marginal distributions of these variables (Patton, 2007).

An n-dimensional copula is a representation of $C:[0,1]^n \to [0,1]$ from the unit cube $[0,1]^n$ into a unit interval, which defines the cumulative n-dimensional distribution function with uniform marginal distributions in the unit interval (Doman, 2011). The application of a conditional copula introduced by Patton facilitates modelling of joint distributions of an n-dimensional vector $\mathbf{y}_t = (y_{1,t},...,y_{n,t})$ $(t=1,...,T)$, conditional in relation to the set of information $\mathcal{F}_{t\text{-}1}$ available by the moment $t-1$; in the analyses in this study they were 2-dimensional vectors. The general model of a conditional copula takes the form (Patton, 2007):

$$y_{1,t}|\mathcal{F}_{t\text{-}1} \sim F_{1,t}(\cdot|\mathcal{F}_{t\text{-}1}),..., y_{n,t}|\mathcal{F}_{t\text{-}1} \sim F_{n,t}(\cdot|\mathcal{F}_{t\text{-}1}), \quad \mathbf{y}_t|\mathcal{F}_{t\text{-}1} \sim F_t(\cdot|\mathcal{F}_{t\text{-}1}), \tag{1}$$

$$F_t(\mathbf{y}_t|\mathcal{F}_{t\text{-}1}) = C_t(F_{1,t}(y_{1,t}|\mathcal{F}_{t\text{-}1}),..., F_{n,t}(y_{n,t}|\mathcal{F}_{t\text{-}1})|\mathcal{F}_{t\text{-}1}), \tag{2}$$

where C_t denotes a copula, $F_{i,t}$ and F_t are respective the marginal distribution function $y_{i,t}$ and the joint distribution function $\mathbf{y}_t$ in moment t.

It was assumed in this study that rates of return $r_{i,t}$ $(i=1,...,n, t=1,...,T)$ from agricultural raw material sub-Indexes are modelled using the ARMA-GARCH model (Doman, Doman, 2009):

$$r_{i,t} = \mu_{i,t} + y_{i,t}, \tag{3}$$

$$\mu_{i,t} = E(r_{i,t}|\mathcal{F}_{t\text{-}1}), \quad \mu_{i,t} = \mu_{0i} + \sum_{j=1}^{P_i} \varphi_{ij} r_{i,t-j} + \sum_{j=1}^{Q_i} \theta_{ij} y_{i,t-j}, \tag{4}$$

$$y_{i,t} = \sqrt{h_{i,t}}\varepsilon_{i,t}, \tag{5}$$

$$h_{i,t} = Var(r_{i,t}|\mathcal{F}_{t\text{-}1}), \quad h_{i,t} = \omega_i + \sum_{j=1}^{p_i} \alpha_{ij} y_{i,t-j}^2 + \sum_{j=1}^{q_i} \beta_{ij} h_{i,t-j}, \tag{6}$$

where $\varepsilon_{i,t} \sim iid(0,1)$. In this study a respetive ARMA model was fitted to the rates of return from sub-Indexes of individual agricultural raw materials and next for the residuals from that models the GARCH(1,1) model was fitted; models with normal, normal skew, Student's *t* and skew Student's *t* distributions were analysed.

It is assumed in the copula-DCC-GARCH model that the joint conditional distribution of an n-dimensional vector $\boldsymbol{\varepsilon}_t$ is modelled using a conditional copula with conditional correlations $\mathbf{R}_t$; in this paper elliptic copulas (Gaussian and Student's *t*) were investigated. The matrix of conditional correlations is determined from the Dynamic Conditional Correlation (DCC) model (Engle, 2002):

$$\mathbf{H}_t = \mathbf{D}_t \mathbf{R}_t \mathbf{D}_t, \;\; \mathbf{D}_t = diag\left(\sqrt{h_{1,t}}, ..., \sqrt{h_{n,t}}\right), \;\; \mathbf{R}_t = \left(diag\left(\mathbf{Q}_t\right)\right)^{-1/2} \mathbf{Q}_t \left(diag\left(\mathbf{Q}_t\right)\right)^{-1/2}, \quad (7)$$

$$\mathbf{Q}_t = \left(1 - \sum_{k=1}^{K} a_k - \sum_{l=1}^{L} b_l\right)\overline{\mathbf{Q}} + \sum_{k=1}^{K} a_k \mathbf{u}_{t-k}\mathbf{u}'_{t-k} + \sum_{l=1}^{L} b_l \mathbf{Q}_{t-l}, \quad (8)$$

where conditional variance $h_{i,t}$ is modelled using the GARCH(p,q) model presented by formula (6), $\overline{\mathbf{Q}}$ is an unconditional matrix of covariance of variables $\mathbf{u}_t$, where $u_{i,t} = y_{i,t} / \sqrt{h_{i,t}}$. It is assumed that parameters a_k, b_l meet the conditions $a_k \geq 0$, $b_l \geq 0$, $\sum_{k=1}^{K} a_k + \sum_{l=1}^{L} b_l < 1$. In a situation when a_k and b_l are equal to zero, the DCC model is reduced to the Constant Conditional Correlation (CCC) model (Bollerslev, 1990). In the empirical analysis parameters of estimated models were determined using the maxmum likelihood method. The semi-parametric method of transformation was applied to the marginal innovations of the GARCH fitted models. Calculations were made in the RCran in the “rmgarch” package developed by Ghalanos.

When the joint distribution of random vairables is elliptic, the dependencies between these variables may be measured using the linear correlation coefficient. In a general case non-linear correlation coefficients, i.e. Kendall's tau or Spearman's ro coefficients, are more appropriate measures. These coefficients are more resistant to extreme observations. In this paper Kendall's tau coefficient was used, based on the difference in probability that changes in two variables occur in the same direction and the probability that these variables change in opposite directions. If (X_1, X_2) is a vector of a pair of random variables and $(\tilde{X}_1, \tilde{X}_2)$ is its independent copula, Kendall's tau coefficient is expressed by the formula (Doman, Doman, 2014):

$$\tau(X_1, X_2) = P\left((X_1 - \tilde{X}_1)(X_2 - \tilde{X}_2) > 0\right) - P\left((X_1 - \tilde{X}_1)(X_2 - \tilde{X}_2) < 0\right). \quad (9)$$

In the case when variables X_1 and X_2 are related through the elliptic copula with the correlation coefficient ρ, Kendall's tau coefficient is presented by the formula:

$$\tau(X_1, X_2) = \frac{2}{\pi} \arcsin \rho. \quad (10)$$

The basic measures of the dependence between extreme values of random variables X_1 and X_2 are provided by the tail dependence coefficients (TDC) in the 2-dimensional distribution. They define the conditional probability of extremely high (low) values of one variable on condition very high (low) values of the other variable are found. If variables X_1 and X_2 having distribution functions F_1 and F_2 are linked with copula C then the correlation coefficient in the upper λ^U and lower λ^L tails are expressed with the following formulas (Doman, Doman, 2014):

$$\lambda^U = \lim_{\alpha \to 1^-} P\left(X_2 > F_2^{-1}(\alpha) \middle| X_1 > F_1^{-1}(\alpha)\right) = \lim_{\alpha \to 0^+} \frac{\hat{C}(\alpha,\alpha)}{\alpha}, \tag{11}$$

$$\lambda^L = \lim_{\alpha \to 0^+} P\left(X_2 \le F_2^{-1}(\alpha) \middle| X_1 \le F_1^{-1}(\alpha)\right) = \lim_{\alpha \to 0^+} \frac{C(\alpha,\alpha)}{\alpha}, \tag{12}$$

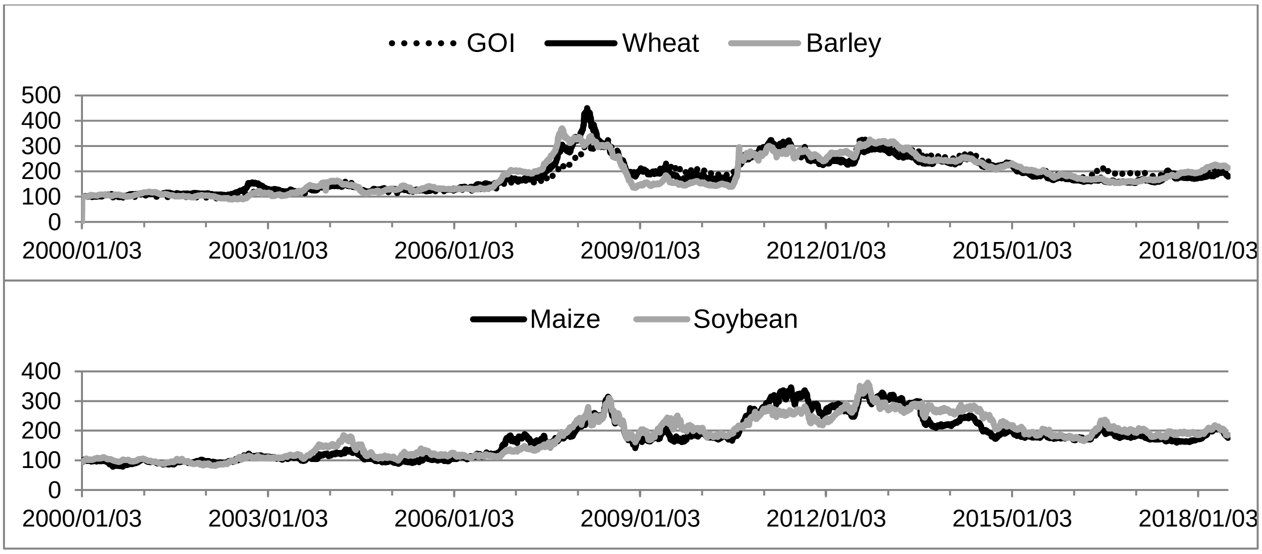
where $\hat{C}(u_1,u_2) = u_1 + u_2 - 1 + C(1-u_1, 1-u_2)$. For the Gaussian copula $\lambda^U = \lambda^L = 0$, while for Student's *t* copula with ν degrees of freedom and the correlation coefficient $\rho > -1$:

$$\lambda^U = \lambda^L = 2t_{\nu+1}\left(-\sqrt{\frac{(\nu+1)(1-\rho)}{1+\rho}}\right). \tag{13}$$

3 Characteristics of data

In this study we used daily sub-Indexes for ceeral grains and oilseeds (wheat, maize, soybean, barley) of the International Grains Council (www.igc.int/en/markets/marketinfo-goi.aspx) from the period from the 3rd January 2000 to the 29th June 2018. The rice sub-Index was excluded due to its series of constant price. Graphs of IGC GOI and its sub-Indexes are presented in Fig. 1.

Figure 1: IGC Grains and Oilseeds Index, Wheat sub-Index, Maize sub-Index, Soybean sub-Index, Barley sub-Index in the period 3.01.2000–29.06.2018



Source: the author's adjustment based on International Grains Council data (www.igc.int/en/markets/marketinfo-goi.aspx)

Analysis of correlations between markets of cereal grains and oilseeds was conducted using series of percentage, logarithmic rates of return from the sub-Indexes calculated from the formula: $r_t = 100\ln(P_t / P_{t-1})$, where P_t denotes the value of a sub-Index on day t. Table 1 presents descriptive statistics for series of rates of return from the sub-Indexes of grains and oilseeds as well as the results of the Ljung-Box test for series of rates of return and their squares. On this basis it was stated that the distribution of rates of return for all the sub-Indexes was characterised by low skewness and leptokurtosis. In all the analysed series a significant autocorrelation was found in the squares of rates of return already at 1 lag. Moreover, in the series for rates of return from grains sub-Indexes a significant autocorrelation was recorded.

Table 1: Descriptive statistics, Ljung-Box test values (Q(1)) with 1 lag for analysed returns and Ljung-Box test values ($Q^2(1)$) with lag 1 for squares of analysed returns

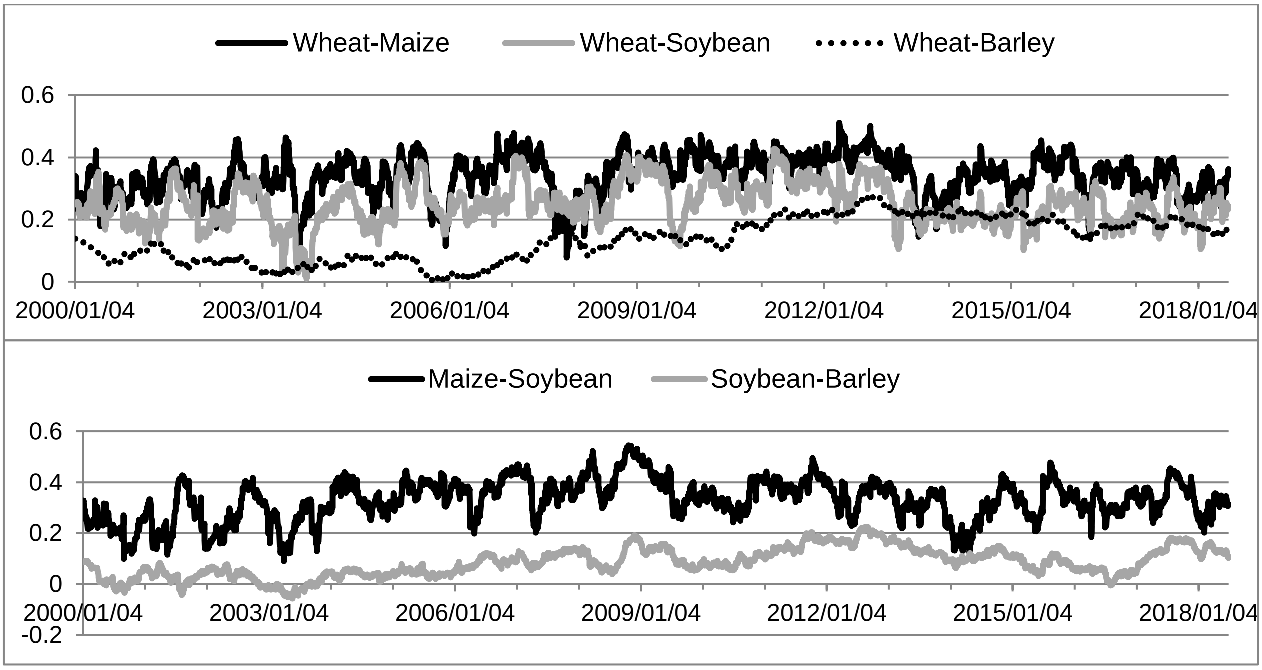
Specification	Wheat	Maize	Soybean	Barley
Min	-4.51	-9.21	-9.51	-9.70
Mean	0.0130	0.0127	0.0139	0.0161
Max	5.85	6.41	7.02	13.49
Std. Dev.	0.81	1.35	1.36	0.85
Skewness	0.21	-0.16	-0.42	0.29
Kurtosis	3.60	3.27	3.68	32.21
Q(1)	**273.05**	**6.07**	0.77	**295.96**
$Q^2(1)$	**182.43**	**78.349**	**100.37**	**206.76**

The rejection of the hypothesis of the Ljung-Box test (there is no autocorrelation) at the significance level of 0.05 is marked in bold.
Source: the author's adjustment

4 Results

Due to the incidence of autocorrelation in the series of rates of return from grains sub-Indexes respective ARMA models were fitted to these series. For the wheat sub-Index it was the ARMA(2,1) model, for maize – ARMA(1,0), for soybean – ARMA(0,0) and barley – ARMA(1,3). In view of the strong ARCH effect already at 1 lag in the series of rates of return from the sub-Indexes of grains and soybean, in the second stage of the study for residuals from the ARMA models the GARCH(1,1) models were estimated with the Student's *t* innovation distribution (the investigated innovation distributions were normal, normal skew, Student's *t*, skew Student's *t*). The ARMA and GARCH models were selected based on the Bayesian information criterion and properties of residuals. In the next stage of the study 2-dimensional copula-DCC-GARCH(1,1) models were estimated using Student's *t* or normal distribution. For the following pairs of sub-Indexes: wheat–maize, wheat–soybean, wheat–barley, maize–soybean in terms of the Bayesian information criterion the copula-DCC-GARCH model with Student's *t* distribution proved to be superior, while for the soybean–barley sub-Index pair the copula-DCC-GARCH model with the normal distribution was better. In turn, for the maize-barley sub-Index pair the copula-CCC-GARCH(1,1) model was estimated with the normal distribution due to the conditional correlation constant in time (the Engle and Sheppard test and the Tse test). The strength of correlations between the rates of return with grains and soybean sub-Indexes in the period of 2000–June 2018 was measured using the dynamic Kendall's tau correlation coefficients (Fig. 2).

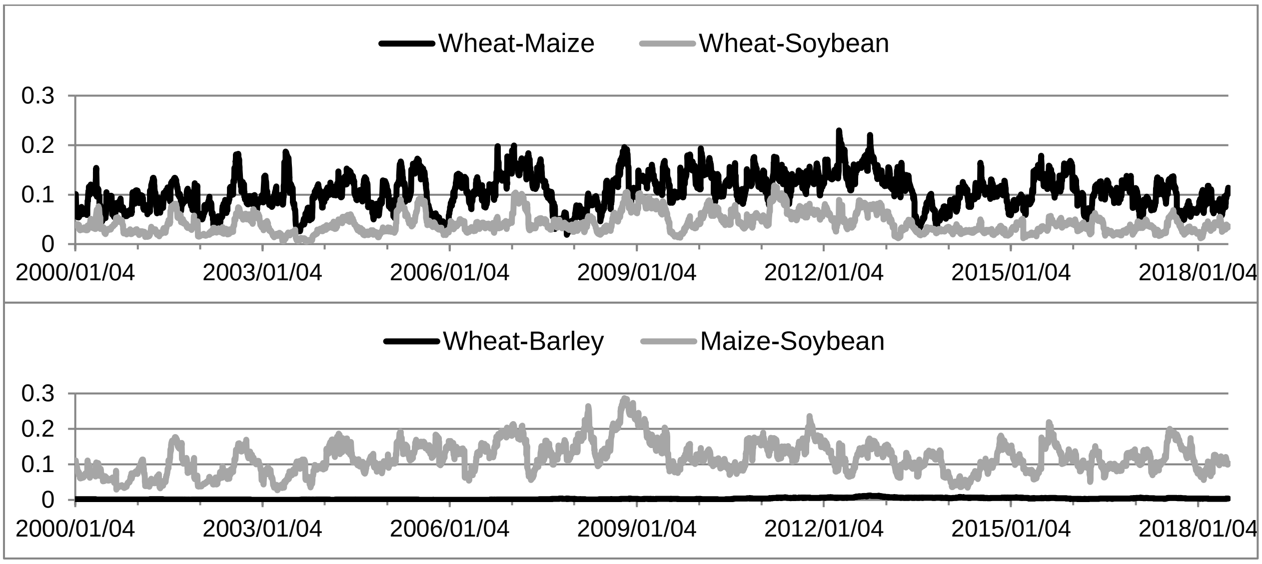
Figure 2: Estimations of dynamic Kendall's tau correlation coefficients for the dependencies between rates of return from sub-Indexes of cereal grains and soybean



Source: the author's adjustment

Among the analysed sub-Indexes of grains and soybean the storngest correlations were foudn between sub-Indexes of wheat and maize, and sub-Indexes of maize and soybean. The value of the condiitonal correlation measured with Kendall's tau coefficient indicated a weak or moderate positive correlation. The results were influenced by the applied measure of correlation, as the conditional correlation measured with Pearson's coefficient indicated for these pairs of raw materials generally moderate or strong correlations. Moreover, the evaluation of the strength of the dependence between raw materials was influenced by the application of aggregate data, since the investigated indexes were formed based on export prices for agricultural raw materials from various parts of the world. It may be assumed that the dpendencies between changes in prices for the analysed raw materials result not only from fundamental factors. This is evidenced by the comparable relatively high values of the conditional correlation for sub-Indexes of wheat and maize for a relatively long period of September 2008 – May 2013. In that period a relatively stable character of the correlation was observed also for the wheat–soybean sub-Index pair with Kendall's tau coefficient of 0.3–0.4 (Pearson's coefficient of 0.4–0.5). It was the period of a financial and economic crisis. Futures contracts for wheat, maize and soybean were included in the major commodity indexes (Zawojska, 2011) and the activity of portfolio investors on the markets of these raw materials was considerable (Tomaszewski, 2015). Quotations for futures contracts for agricultural raw materials responded to the market information and frequently were reference points to the actual transaction on agricultural markets (Hernandez, Torero, 2010; Zawojska, 2011). The dependencies observed for the pair of maize and soybean sub-Indexes were different in character. In this case the strongest conditional correlation was observed in the period of March 2005 – June 2009, November 2010 – January 2012. This may be related with the increased use of these raw materials to produce biofuel. The weakest conditional correlation was recorded for the barley sub-Index and the other sub-Indexes, while for the maize–balrey sub-Index pair it was constant (Kendall's tau coefficient was 0.1, Pearson's coefficient was 0.15). In the case of the other pairs of grains and soybean sub-Indexes the conditional correlation structure changed in time.

Figure 3: Estimations of the dynamic correlation coefficients in the upper and lower tails for rates of return from grains and soybean sub-Indexes



Source: the author's adjustment

Dependencies between rates of return from the sub-Indexes of grains and soybean in the lower and upper tails in the period of 2000 – June 2018 are presented in Fig. 3. For pairs of sub-Indexes of soybean and barley and for maize and barley the 2-dimensional GARCH model with the normal copula was applied, which means that the probability of transferring extreme events between these markets was 0. In the case of the wheat and barley sub-Index pair the 2-dimensional GARCH model was estimated with Student's *t* copula with 18 degrees of freedom, which means that correlations in tails were very weak – the probability of transferring extreme events did not exceed 0.02. Much stronger dependencies in tails were observed for the pairs of sub-Indexes for wheat and soybean, wheat and maize as well as maize and soybean, particularly in the case of two latter pairs of raw materials. The greatest probability of spillovers between maize and soybean markets were observed in March 2008, the last quarter of 2009, October 2011 and August 2015. They were periods of dramatic drops in prices for these raw materials. In turn, the greatest probability of spillovers between wheat and maize markets was found in October 2006, January 2007, October 2008, April and October 2012, while only in October 2008 the increase in the correlation was accompanied by a considerable drop in prices of these raw materials.

5 Concluding remarks

The paper presents an analysis of correlations between rates of return from sub-Indexes of grains and soybean from the International Grains Council in the period 2000 – June 2018. Results of this analysis indicate that the barley market is very weakly connected with the markets of the other cereals and soybean, while extreme events are not transferred between these markets. Stronger (weak or moderate) positive correlations changing in time were observed between markets of wheat and maize, maize and soybean, wheat and soybean. Relatively stable linkages were found between wheat and maize markets and wheat and soybean markets during the economic crisis. They were stronger than in the other subperiods. This means that the structure of dependencies between changes in prices of these raw materials did not depend only on fundamental factors, but also changed under the influence of changes taking place on the financial markets. Probability of transferring extreme events between markets of wheat and maize, wheat and soybean more frequently increased also during the economic crisis. The greatest probability of transferring extreme events was recorded for markets of maize and soybean. It seems that frequent increases in this probability in the period 2005–2012 may have resulted from the influx of information on the growing demand for these raw materials in the biofuel sector. Summing up, it needs to be stated that the strongest relationships were found in the period of 2000 – June 2018 for the markets of maize and soybean as well as markets of wheat and maize, while these linkages changed in time. In this research we used a relatively simple approach for investigating dependencies between world grain and oilseed markets. In future research we will apply a more complicated dependence structures (e.g. Vine copulas).

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