Scientific Journal Warsaw University of Life Sciences – SGGW
Problems of World Agriculture volume 17 (XXXII), number 4, 2017: 249–262
DOI: 10.22630/PRS.2017.17.4.101

Jacek Pera[1]
Cracow University of Economics

Linear and Non-linear Relationships Between Shares of the Agri-food Industries of the Warsaw Stock Exchange. Risk Aspect

Abstract. Despite a wide range of research on the agricultural market conducted so far, relatively little attention has been devoted to a comprehensive analysis of linear and non-linear causality in relation to the entire agri-food sector in Poland, in the context of risk. The objective of this study is therefore to analyze the linear and non-linear relationships between shares of WSE's agri-food industry sectors in terms of risk. The study covered three sectors of agri-food sector currently existing on the WSE (29 listed companies): Foods (21 listed companies), Agricultural Production and Fisheries (5 listed companies) and Food and Foodstuffs and fast-trafficking foodstuffs (3 listed companies). The existence of linear relationships was verified using the test procedure proposed by Hong, Liu, Wang and Łęt, while non-linear relationships were verified using the Diks-Panchenko, Orzeszko and Osińska tests's. The study was carried out on the basis of data from companies of the agri-food industry listed on the Warsaw Stock Exchange in the period from 1 May 2010 to 1 May 2017. The chosen research methodology was dictated by the correlation with investment risk on the WSE. The strongest and most enduring dependencies have been found in the agricultural and fisheries sectors. In the foodstuff sector and the fast-marketable sector, the risk of investment in the listed companies was temporary.

Key words: shares, risk, causal linear relationship, non- causal linear relationship, agri-food industry

JEL Classification: E220, C510, L160, Q100, Q180,

Introduction

Globalisation - and as a result, the dynamics in the development of modern financial markets has been reflected also in the classic commodity market, where (similarly to the financial market) the goal of every investor is to achieve the highest possible profit while maintaining an optimal, acceptable level of risk. Skilful risk forecasting is therefore an important element of the investment strategy. As a result, in recent years commodity markets have become increasingly similar to financial markets due to the motives and strategies of their participants, many tools and methods of econometrics and financial engineering are used in commodity markets.

For a few years now, the contemporary Polish literature of the subject has been using financial econometrics methods to analyze the commodity market, including the agricultural market. An important area, whose research has become popular in recent years, is the analysis of causation in agricultural markets. He dealt with this issue, among others, with the following issues Figiel (2002), which examined causality in the sense of Granger in the sense of intervention prices of buying wheat and rye and their market purchase prices, causality in the sense of Granger in relation to domestic rye and wheat prices in particular regions of Poland and causality in the sense of Granger in relation to domestic

[1] PhD, International Chair for Economic Relations, Cracow University of Economics, Rakowicka St. 27, 31-510 Kraków, e-mail: peraj@uek.krakow.pl

and selected world monthly wheat prices. Dudek (2008) addressed the analysis of causal links between feed cereal and pig livestock prices. Rembeza (2009), investigating the relationship between prices of agricultural products in Poland and European Union countries, conducted causality tests of wheat prices for the Polish, French and American markets as well as prices of pork livestock from the Polish, Danish and Dutch markets.

Gędek (2009) studied the relationship between pork prices on the Polish market and selected European Union markets and used the Granger test to investigate causality for prices of pork half-carcasses in Poland, Germany and France. Rembeza and Chotkowski (2010) investigated the price links between the small markets on the potato market. Rembeza (2010) also presented the results of Granger's causality test for cereal prices in Poland and Germany, France and the USA for prices of pigs in Poland, Denmark and the Netherlands, for wheat and pig and poultry, as well as rye and pigs. In the same work, he used the causality analysis of Granger in order to determine the direction of price impulses flow for prices of raw materials and preparations such as: meat and pork and ham, wheat and wheat flour, wheat bran, rye and rye flour and rye bran and rye bran. Gędek (2010) studied causality in the sense of Granger as regards prices of wheat, piglets and pork livestock on the local market of the Ryk area. Tłuczak (2011) investigated the impact of purchase prices of livestock on retail prices of meat and used the Granger test to identify causal links between purchase prices and retail prices of bone-in and boned beef and veal, gutted chickens and cattle, pigs and poultry. Hamulczuk and Klimkowski (2011) studied the relationship between oil prices and wheat prices in Poland. The research using the Granger's test to identify causal links between cereal market prices in Poland was also conducted by Krawiec (2013) and Łęt (2014) as regards the risk of selected WSE sectors in Warsaw. The trade in agricultural and food products on the stock exchange (the conception of the essence of the commodity exchange) was examined by Dykiel, Liszka (2015).

Despite such a wide range of research on the agricultural market conducted so far, relatively little attention was devoted to a comprehensive analysis of linear and non-linear causality in relation to the entire agri-food sector in Poland, in the context of risk. The objective of this study is therefore to analyze the linear and non-linear relationships between shares of the WSE's agri-food industry sectors in terms of risk. The study covered three sectors of agri-food sector currently existing on the WSE (29 listed companies): Food (21 listed companies), Agricultural Production and Fisheries (5 listed companies) and Foodstuffs and fast-trafficking foodstuffs (3 listed companies).

The existence of linear relationships was verified using the test procedure proposed by Hong, Liu, Wang (2009) and Łęt (2014), while non-linear relationships were verified using the Diks-Panchenko test's (Diks, Panchenko, 2006) and Orzeszko and Osińska (Orzeszko, Osińska, 2007).

The survey was conducted based on data from listed companies of the agri-food industry listed on the Warsaw Stock Exchange in the period from 1 May 2010 to 1 May 2017.

The author hopes that the conducted research will contribute to a methodical and comprehensive approach in the analysis of causality of linear and non-linear relationships.

Linear and non-linear causes of risk. Literature review

The causes behind the risk in the sense of Granger is related to the flow of information on the financial markets. For this reason, it is referred to as information causality (Osińska, 2011). Investors, in response to the incoming information, make decisions that result in financial capital movements between the markets (Osińska, 2008). Thus, the risk of one financial instrument may precede that of another.

The concept of causality in economics is widely discussed from the point of view of methods of axiomatic description and methods of analysis. Pearl (2000) applies methods of graph theory based on probabilistic bases in Bayesian terms; Hoover (2001) stresses the need for a causal structure analysis and uses tools of multi-equation econometric models; Cartwright (2010) refers to philosophical fundamentals and criticizes Pearl and Hoover's approach; the paper (Syczewska, Struzik, 2014) contains an overview of selected methods of causality testing; Barnett, Barret, Seth, (2009) and Hlaváčkova-Schindler et al. (2011) demonstrated the equivalence of the linear Granger test for the normal distribution variables.

A linear version of the Granger test is used to detect causality in average. Krawiec (2012) analyses quotations of selected Polish commodity funds and world prices of the most important goods, for the period from 01.2009 to 12.2011. It also tests the linear causality of Granger's rate of return in logarithmic terms., $r_t = \ln P_t - \ln P_{t-1}$, and states that there are causal links from the S&P500 index to some but not all raw material funds. Misiuk, Zajkowska (2010) based on daily data from 01.2004 to 03.2010 showed that WIG20 influences DAX, BUX, ATX and S&P500, and is influenced by CAC, PX (index for the Czech Republic), BUX (Hungarian index), ATX (Austrian index), FTSE, FTSE MIB (Italian indexes). Applications in financial econometrics often concern causality in variance (Cheung, Ng 1996) and risk. Fałdziński, Osińska, Zdanowicz (2012) recall that the original idea of Granger's causality in risk assumes the use of Value at Risk as a measure of risk, and expands the use of the test with Expected Shortfall and spectral measurements. The risk factors are tested for the period before the crisis (1.02.2006-31.07.2008) and during and after the crisis (1.08.2008-18.02.2011).

The concept of causality in the sense of Granger in the sense of risk of Hong, Liu and Wang has been developed along the lines of causality in variance. As Hong, Liu and Wang (2009) say, variance alone is not in a good position to capture risk figures in the event of extreme financial market movements. Variation reflects both expected values of above-average losses and profits. Risks, on the other hand, reflect uncertainty as to the potential losses that an investment in a financial instrument could incur. In addition, the occurrence of risk causal relationships between the two instruments may occur despite the rejection of similar hypotheses in relation to mean and conditional variance (Hong, Liu, Wang, 2009), because risk causality may occur, among other things, in situations where there are common changes in the obliquity.

The non-linear aspects of causation have already been addressed by Granger (Granger, Teräsvirta, 1993; Granger, Maassoumi, Racine, 2004). Bruzda (2007) discusses the conditions that must be fulfilled by an ideal measure of functional dependency of two stochastic processes: it is to be well defined for both continuous and discrete variables; equal to zero for independent variables; normalized to $\langle 0,1 \rangle$ or $\langle -1,1 \rangle$; shall meet the distance conditions, and for variables of normal distribution shall be equal to the correlation coefficient or one of its simple functions. Diks and Panchenko as one of the arguments justifying the need to modify the Hiemstra-Jones test, quoted the fact that the test more often rejected the hypothesis of no causality than the Granger's linear test, which in their opinion weakened the conclusion based on the HJ test in the published practical applications. Diks and Panchenko (2005) concluded that the Hiemstra-Jones test (1994) could reject the hypothesis of no causality even if the Granger's linear test definitely points to it. So they proposed an adjusted version of this test. The test T_n (Diks, Panchenko, 2006) can be used to detect non-linear causations.

Data and methods

The aim of the survey is to analyze linear and non-linear relationships between shares of WSE's agri-food industry sectors in terms of risk. Three currently operating agri-food sectors of the WSE (29 listed companies) were analysed: Foods - F (21 listed companies), Agricultural Production and Fisheries - APF (5 listed companies) and Foodstuffs and fast-trafficking foodstuffs - FFF- (3 listed companies) – Table 1. The research was conducted on the basis of companies data for the period from 1 May 2010 to 1 May 2017.

Table 1. List of companies in the Warsaw Stock Exchange agri-food sector (data on 10.2017)

Nazwa spółki	Foods	Agricultural production and fishing	Foodstuffs and fast-trafficking foodstuffs
ADM Czernin [ADM]	YES	NO	NO
Atlanta Poland SA [ATP]	YES	NO	NO
Bakalland SA [BAK]	YES	NO	NO
Colian Holding SA [COH]	YES	NO	NO
Gobarto SA [GOB]	YES	NO	NO
Graal SA [GRA]	YES	NO	NO
Helio SA [HEL]	YES	NO	NO
Indykpol SA [IND]	YES	NO	NO
Kernel Holding SA [KEH]	YES	NO	NO
Kruszwica SA [KRU]	YES	NO	NO
Makarony Polskie SA [MAP]	YES	NO	NO
Mieszko SA [MIE]	YES	NO	NO
Milkiland NV [MIL]	YES	NO	NO
Mispol SA [MIS]	YES	NO	NO
Ovostar Union NV[OVU]	YES	NO	NO
Pamapol SA [PAM]	YES	NO	NO
Tarczyński SA [TAR]	YES	NO	NO
Wawel SA [WAW]	YES	NO	NO
Wilbo SA [WIL]	YES	NO	NO
ZM Henryk Kania SA [ZHK]	YES	NO	NO
ZPC Otmuchów SA [ZPC]	YES	NO	NO
Agroton Plc [AGR]	NO	YES	NO
Astarta Holding NV [ASH]	NO	YES	NO
AUGA Group AB [AUG]	NO	YES	NO
IMC SA [IMC]	NO	YES	NO
KSG Agro SA [KSG]	NO	YES	NO
Delko SA [DEL]	NO	NO	YES
FH Jago SA [FHJ]	NO	NO	YES
North Coast SA [NOC]	NO	NO	YES

Source: The author's own development.

The choice of sectors was dictated by the place of publication of the article. The survey covered all companies in a given sector, regardless of the level of capitalisation of the listed company and the liquidity of shares on the stock exchange.

The existence of linear relationships was verified using the test procedure proposed by Hong, Liu, Wang and Łęt, while the Diks-Panchenko, Orzeszko and Osińska tests's were used to verify non-linear relationships.

The test procedure proposed by Hong, Liu and Wang is based on the examination of correlation coefficients between time series containing information on the VaR value-at-risk values being exceeded by the return of a given listed company.

According to Tody's, Yamamoto, Bauer and Maynard (Toda, Yamamamoto, 1995; Bauer, Maynard, 2012), for non-stationary variables, it is advisable to select the optimal number of 2 delays for the VAR model, and then increase it by a number equal to the number of rows of integration of variables *d*.

The linear causality test of Granger variable pairs shall be carried out as follows: the equations of the VAR model with the same number of delays for both variables, k, are estimated and the total significance of delays for a given variable is tested in the equation explaining the second variable:

$$y_t = \alpha_{10} + \sum_{j=1}^{k} \alpha_{1j}\, y_{t-j} + \sum_{j=1\,1j}^{k} x_{t-j} + \epsilon_{1t} \tag{1}$$

$$y_t = \alpha_{20} + \sum_{j=1}^{k} \alpha_{2j}\, y_{t-j} + \sum_{j=1\,2j}^{k} x_{t-j} + \epsilon_{2t} \tag{2}$$

In the equation (1) H_0: $\beta_{11} = \beta_{12} = \ldots = \beta_{1k} = 0$ means that there is no causal link in the sense of Granger between the variable *X* do *Y*. In the equation (2) H_0: $\beta_{21} = \beta_{22} = \ldots = \beta_{2k} = 0$ means no linear causality from *Y* to *X*.

Diks and Panchenko concluded that the Hiemstra-Jones test's (1994) could reject the hypothesis of no causality even if the Granger's linear test definitely points to it. So they proposed an adjusted version of this test. The run of the Diks-Panchenko test's is as follows: the *X* variable is the cause in the sense of Granger for *Y* if current and delayed values $X = x_t, x_{t-1}, \ldots, x_{t-n}$ contain additional information about future values $Y = Y_{t+1}, Y_{t+2}, \ldots, Y_{t+n}$, not included in the current and delayed values of this variable. Authors focus on the case when *X*'s impact on Y_{t+1} is investigated. Diks and Panchenko tested the conditional independence and the finite number of delays.: $Y_{t+1} \mid (X_t, X_{t-1}, \ldots, X_{t-lx+1}, Y_t, Y_{t-1}, \ldots, Y_{t-ly+1}) \sim Y_{t+1} \mid (X_t, X_{t-1}, \ldots, X_{t-lx+1})$, where: l_x, l_y means the number of delays taken into account for a given variable. The test is an improved version of the Hiemster-Jones test, comparing the differences between conditional distributions. Diks and Panchenko applied one delay for both variables and the forecast for one period. If: $(X_t, Y_t, Y_{t+1}) = (X, Y, Z)$ *X* and *Y* will be strictly stationary variables. A null hypothesis with no causality means that a conditional distribution *D* relative *X* and *Y* is as follows *D* relative *Y*. The combined boundary distribution and spacing is as follows:

$$f_{X,Y,Z}(x, y, z) / f_{X,Y}(x, y) = f_{X,Z}(x, z) / f_Y(y) \tag{3}$$

Diks and Panchenko show flaws in approximating the difference between the two sides of this formula with the correlative integral used in Hiemstry-Jones's work, and derive their own version of the formula:

$$g_g \equiv E\,[(f_{X,Y,Z}\,(X,Y,Z)\,f_Y\,(Y) - f_{X,Y}\,(X,Y)\,f_{Y,Z}\,(Y,Z)] \qquad (4)$$

where: $g\,(X, Y, Z)$ is a positive weight function; for $g\,(X, Y, Z) = f_Y^2\,(Y)$.

On the assumption of zero hypothesis truthfulness, the expression in round brackets shall be zeroed. The zero hypothesis is rejected if the calculated value of test statistics is high.

Based on the above relationships – the study used an estimator based on the indicator function.:

$$T_n\,(\square) = \frac{(2\,)^{-dx-dy-dz}}{n(n-1)\,(n-2)} \sum i\,[\sum k, k \neq i \sum j, j \neq i\,(l_{ik}^{X,Y,Z} l_{ij}^{Y} - l_{ik}^{X,Y} l_{ij}^{Y,Z})] \qquad (5)$$

Where: n – number of observations, d_x – vector dimension X, indicator function $l_{ij}^W = l\,(\square\, W_i - W_j \square \leq \square)$ equal to 1 if □ W_i - W_j□ ≤ □ - 0 in the opposite direction.

Results

The article presents an analysis of linear and non-linear relationships between shares of WSE's agri-food industry sectors in terms of risk in the period from 1 May 2010 to 1 May 2017. The subject of the empirical illustration were three currently existing on the WSE agri-food sector in the number of 29 listed companies. Verification of the existence of linear relationships was performed using the test procedure proposed by Hong, Liu, Wang and Łęt. For the verification of non-linear relationships, the Diks-Panchenko, Orzeszko and Osińska tests's were used. The tests were performed for the long position.

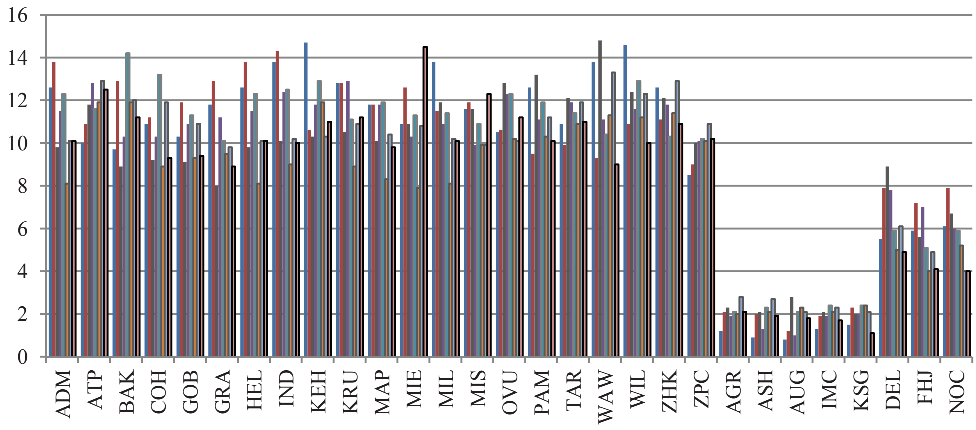

Fig. 1. Percentage logarithmic returns in the period 01.05.2010 - 01.05.2017

Source: The author's own development based on Warsaw Stocks Exchanges.

As far as the linear part is concerned, Figure 1 represents the logarithmic percentages of the surveyed listed companies in the period considered. The most likely are the F and FFF sector returns. The least likely are the returns of the APS sector. Quotations of all shares have been subject to relatively high volatility since 2014.

Table 2. Descriptive statistics for time series and standard deviation for the period 01.05.2010 -01.05.2017

Segment	Companies	Minimal	Average	Maximum	Standard deviation
F	ADM	-2.232	+0.231	+18.878	14.989
	ATP	-1.231	+0.324	+10.854	7.658
	BAK	-3.342	+0.874	+11.232	7.659
	COH	-8.989	+0.542	+10.999	6.341
	GOB	-5.231	+0.762	+9.232	8.767
	GRA	-4.322	+0.162	+7.898	9.651
	HEL	-5.431	+0.167	+10.767	9.342
	IND	-7.342	+0.421	+11.231	9.125
	KEH	-8.342	+0.323	+10.342	9.132
	KRU	-6.232	+0.521	+10.111	8.321
	MAP	-5.231	+0.555	+9.342	9.435
	MIE	-6.781	+0.765	+9.444	9.671
	MIL	-8.909	+0.898	+9.232	9.324
	MIS	-8.676	+0.343	+10.111	9.312
	OVU	-4.454	+0.212	+10.233	9.333
	PAM	-6.788	+0.432	+11.111	9.767
	TAR	-4.989	+0.123	+9.909	9.344
	WAW	-5.999	+0.231	+9.999	9.222
	WIL	-8.909	+0.222	+10.001	9.011
	ZHK	-7.771	+0.454	+11.212	8.320
	ZPC	-4.456	+0.542	+10.221	8.999
APF	AGR	-14.232	-0.012	+5.232	1,232
	ASH	-10.221	-0.023	+3.231	1.111
	AUG	-13.234	-0.001	+1.323	1.325
	IMC	-12.453	-0.011	+2.323	1.453
	KSG	-13.893	-0.021	+1.111	1.621
FFF	DEL	-8.999	+0.015	+7.899	5.342
	FHJ	-9.898	+0.001	+7.342	4.239
	NOC	-9.763	+0.003	+7.221	4.554

Source: The author’s own development.

Table 2 presents the most important descriptive statistics of the series considered. All listed companies with the exception of APF showed a positive or close to zero average rate of return. The series corresponding to the F sector shares had the highest standard deviation and the highest mean deviation. The FFF sector is the lowest average.

Table 3 contains the results of risk causality tests between the aforementioned pairs of listed companies in the analysed sectors. In addition, it illustrates the number of delays in the VAR model for the whole trial, based on the Akaike, AIC, Bayesian Schwarz, BIC, and Hannan Quinna, HQC criteria.

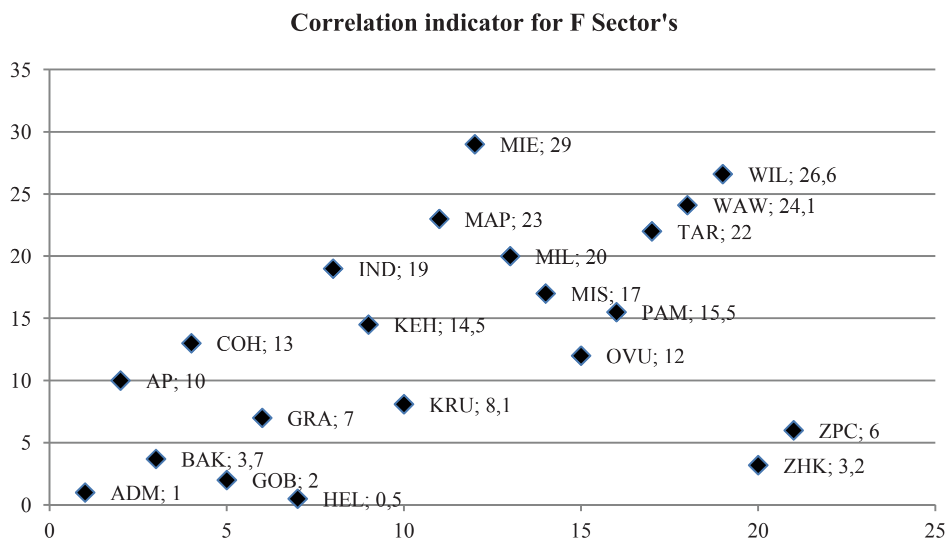

Fig. 2. Correlation of F sector companies in the period 01.05.2010 - 01.05.2017

Source: The author's own development.

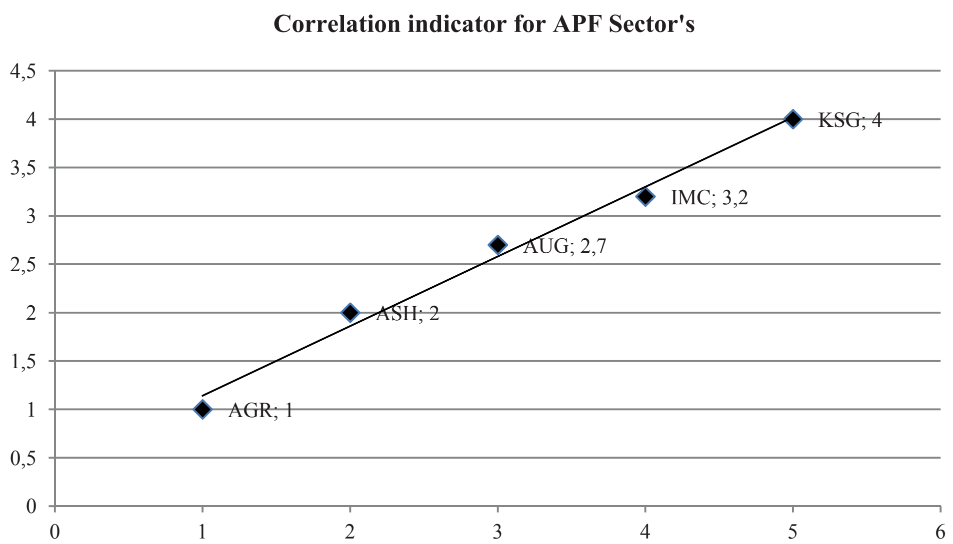

Fig. 3. Correlation of APF sector companies in the period 01.05.2010 - 01.05.2017

Source: The author's own development.

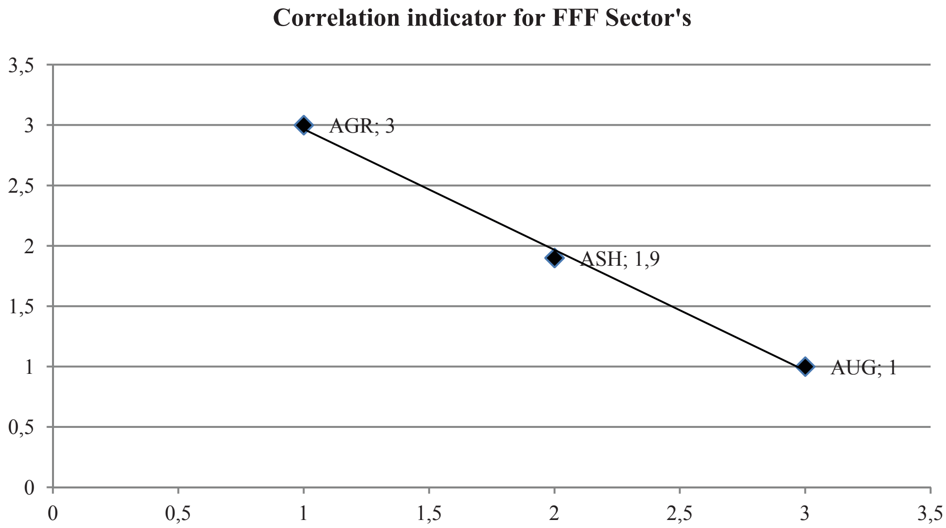

Fig. 4. Correlation of FFF sector companies in the period 01.05.2010 - 01.05.2017

Source: The author's own development.

In the APF sector, strong and lasting causal relationships in the sense of Granger in risk have been detected (Figure 3). In the sector, extreme falls of all APF companies were preceded by the risk of an above-average loss on the shares of these listed companies. Particularly strong and long-lasting relationships exist here between AGR-KSG, AUG-IMC and ASH-KSG. In the case of FFF listed companies (Figure 4), there was a situation in which the direction of dependency coincided with the relationship between the capitalisation of the listed company concerned. The sector is characterised by a moderate significance of risk dependence. In the last analysed sector F (Figure 2), it should be stated that the risk was negligible among the surveyed companies in this sector of causal relationships in the sense of Granger. This situation is likely to be influenced by the general nature of the sector and the profile of the listed companies that make up the sector.

Correlation of all 29 variables clearly confirms the results of the research obtained so far. There is a strong positive linear correlation in the APF sector. This means that the companies in this sector are generating the risk arising from the loss on the shares of these companies. The reason for this is the profile of the sector, which includes these companies. Recent years have seen progressive losses in the agricultural production and fisheries sector. The sector needs a lot of funding. Currently it is a development sector, but not very profitable. Existing EU regulations also limit the development of this sector. For the sector: Fishing is still limited and strictly limited time to catch fish. In practice, this means periodicity in profits. The attractiveness of this sector is also significantly affected by the lack of foreign capital. All this influences the profitability of this sector, which has remained unchanged for almost a few years. Therefore, there is little interest of stock exchange investors in shares of APF companies. In practice, this means that the value of APF companies listed on the Warsaw Stock Exchange is decreasing.

Table 3. Causality test results by sector for the period 01.05.2010 - 01.05.2017

Segment	Companies	M*1	M5	M10	M20	M50	M100	Cause of Ganger's $\boldsymbol{H_0}$
F	ADM	1.234	0.432	2.343	3.451	6.878	7.999	NO
	ATP	1.001	2.323	2.441	3.999	6.999	7.345	NO
	BAK	1.898	0.232	3.879	4.878	6.001	7.989	NO
	COH	1.671	1.221	4.676	4.793	6.565	7.545	NO
	GOB	1.990	2.223	4.233	5.343	6.111	7.222	NO
	GRA	1.232	2.998	4.231	5.555	6.435	7.342	NO
	HEL	1.232	2.222	4.887	5.212	6.231	7.432	NO
	IND	1.008	2.111	4.665	6.321	6.343	7.123	NO
	KEH	1.121	2.241	4.221	5.453	6.777	7.398	NO
	KRU	1.565	2.222	4.888	4.567	6.989	7.767	NO
	MAP	1.111	3.878	4.777	5.786	6.454	7.897	NO
	MIE	1.889	4.767	4.222	5.989	6.767	7.455	NO
	MIL	1.900	3.232	3.878	5.343	6.888	7.344	NO
	MIS	1.112	2.898	5.342	5.343	6.323	7.234	NO
	OVU	1.111	2.898	2.333	5.232	6.777	7.867	NO
	PAM	1.567	2.333	2.999	6.323	6.344	7.777	NO
	TAR	1.232	1.232	2.899	5.764	6.233	7.985	NO
	WAW	1.878	2.344	2.677	5.989	6.899	7.090	NO
	WIL	1.223	2.232	2.888	5.878	6.900	7.459	NO
	ZHK	1.111	2.345	2.777	5.888	6.553	7.754	NO
	ZPC	1.001	2.245	2.990	5.998	6.232	7.762	NO
APF	AGR	10.098	11.656	13.898	15.768	16.123	18.898	YES
	ASH	10.768	11.888	13.343	15.435	16.899	17.199	YES
	AUG	10.777	11.453	13.456	15.879	16.234	17.348	YES
	IMC	10.989	11.899	13.243	15.677	16.989	18.009	YES
	KSG	10.676	11.009	13.789	15.345	16.776	17.565	YES
FFF	DEL	4.878	5.787	6.554	6.878	7.676	10.767	YES/NO
	FHJ	4.878	5.888	6.435	6.989	7.990	10.671	YES/NO
	NOC	4.999	5.666	6.897	6.453	7.876	10.129	YES/NO

M*- Number of days of delay.

Source: The author's own development.

The situation is better for the FFF sector: Food and fast-moving products. There is a strong negative linear correlation. In practice, this means that there is a decreasing risk of equity investments in this sector. The profile of this sector and the interest in foreign capital play an important role here. The fast-moving articles that make up this sector generate a high rate of growth in profits and investment. This in turn has led to a growing interest of stock market investors in investments in this sector. The high level of competitiveness in this sector means that further profitability forecasts for equity investments in companies in this sector are positive. Therefore, further low investment risk in shares of this sector may be forecast.

The lack of linear correlation and therefore neutral risk is observed in the last analysed sector: F. This sector includes 21 companies from the food sector. The sector's profile, prospects of its further development, dynamics, growing interest in foreign capital and dispersion of investments mean that in the case of this sector we can only speak of a lack of any correlation. The dispersion of the sector causes great variability and variety of offered goods. In practice, this means high dynamics on the profit and loss side. This dynamics therefore indicates that there is no correlation in the sector concerned.

The Diks- Panchenko (Table 4) test's was calculated with a default value of 0.5 and the T_n test statistics were calculated for delays from 1 to 5. The results of the test calculations indicate that the statistics can have different values with different number of delays of *X* and *Y* variables.

Table 4. Results of Diks-Panchenko test's for returns of shares in agri-food companies in the period 01.05.2010 - 01.05.2017 (average)

Y	ADM	ATP	BAK	COH	GOB	GRA	HEL	IND	KEH	KRU	MAP
1	+1.239	+4.873	+3.878	+7.990	+5.898	+9.871	+7.676	+10.564	+8.345	+9.001	+10.001
2	+1.349	+5.231	+2.989	+7.342	+5.342	+8.545	+8.889	+11.231	+8.129	+9.132	+12.012
3	+1.901	+1.287	+9.777	+7.888	+5.878	+6.342	+9.888	+9.063	+9.389	+8.990	+13.564
4	+1.122	+10.987	+8.567	+7.234	+8.567	+7.878	+6.234	+10.123	+8.101	+8.778	+14.564
5	+1.909	+6.909	+7.342	+8.991	+9.573	+5.342	+7.777	+11.234	+7.576	+7.888	+10.198
6	+1.111	+8.767	+6.776	+9.912	+6.989	+4.342	+8.345	+12.456	+6.897	+9.787	+11.129
7	+1.887	+7.887	+3.342	+8.567	+7.898	+6.787	+9.767	+10.345	+8.432	+9.787	+10.564
8	+1.567	+8.223	+9.777	+6.778	+9.651	+8.787	+8.349	+11.989	+9.678	+9.001	+9.081
	MIE	MIL	MIS	OVU	PAM	TAR	WAW	WIL	ZHK	ZPC	
1	+4.567	+7.899	+8.897	+9.345	+7.989	+8.991	+9.989	+8.998	+10.767	+9.991	
2	+7.897	+9.999	+9.998	+9.678	+9.323	+9.002	+9.888	+9.456	+10.999	+9.101	
3	+3.456	+7.234	+10.187	+9.001	+8.786	+8.453	+9.000	+9.434	+10.889	+10.101	
4	+9.879	+8.345	+11.675	+9.101	+9.457	+10.001	+8.564	+8.456	+10.999	+11.123	
5	+8.199	+9.129	+10.655	+9.878	+9.577	+10.222	+9.111	+9.788	+10.000	+9.990	
6	+9.234	+8.342	+11.234	+9.888	+8.888	+10.009	+9.221	+9.999	+11.129	+9.012	
7	+8.145	+9.432	+9.123	+9.001	+9.378	+9.901	+8.565	+9.878	+10.789	+9.238	
8	+8.345	+8.323	+8.128	+9.888	+9.991	+12.897	+7.999	+9.999	+12.789	+8.998	
	AGR	ASH	AUG	IMC	KSG	DEL	FHJ	NOC			
1	-0.767	-0.567	-0.545	-0.453	-0.567	+0.239	+0.186	+0.355			
2	-0.234	-0.789	-0.567	***+2.989***	-0.761	+0.678	+0.129	+0.115			
3	-0.567	-0.323	-0.675	-0.129	-0.562	+0.111	+0.131	+0.189			
4	-0.897	-0.332	***+1.786***	-0.763	-0.431	+0.132	+0.142	+0.121			
5	-0.678	-0.123	-0.189	-0.221	-0.330	+0.189	+0.122	+0.155			
6	-0.677	-0.675	-0.121	-0.777	-0.141	+0.168	+0.155	+0.187			
7	-0.889	-0.898	-0.156	-0.232	-0.871	+0.134	+0.199	+0.198			
8	-0.765	-0.198	-0.909	-0.111	***+4.999***	+0.122	+0.112	+0.110			

Source: The author's own development.

The null hypothesis of no causality was in most cases rejected and the causal relationships were weak in two sectors: F and FFF. In three cases of the listed companies AUG, IMC and KSG, the T_n test rejected the hypothesis of no causality.

The presented results of causality testing refer to earlier studies on the use of stock market indices. The study carried out in this work complements these findings with conclusions on risk causation. So far, causality studies in the sense of Granger have been conducted by: B Łęt, M. Krawiec, E.M. Syczewska i W. Orzeszko, M. Osińska. Obtained research results clearly indicate the validity of the adopted research method. The results revealed linearity and non-linearity of the analysed data (similarly to this analysis). B. Łęt stressed that the results of the tests showed in most cases a risk causality between the examined instruments in the banking, fuel and raw material sectors. In the case of M. Krawiec, the results obtained, unequivocally, will reveal the occurrence of causal relationships in the sense of Granger on the cereals market in Poland in the years 2007-2011. E.M. Syczewska showed causal relationships between the USDPLN price and the corresponding stock exchange indices, which are represented by S&P500 for the United States and WIG20 for the Warsaw Stock Exchange. W. Orzeszko and M. Osińska showed causal relationships between price changes and the Warsaw Stock Exchange turnover changes; price changes were determined by changes in turnover. All the conducted research also indicates a need for further analysis of the causality of linear and non-linear events.

Conclusions

The aim of this study was to analyze the linear and non-linear relationships between shares of Warsaw Stock Exchange agri-food industry sectors in terms of risk. Calculations made with the help of tests - the Granger linear test and the Diks-Panchenko test's - showed such or no such dependence.

Diks and Panchenko tests's T_n gave the same result as the Granger test. The null hypothesis of non-causality was in most cases rejected and the causal relationships were weak for two sectors: F and FFF.

In three cases of the listed companies: AUG, IMC and KSG, the test T_n rejected the hypothesis of non-causality. It did not happen that the test T_n rejected zero hypothesis if the Granger linear test did not reject it – in this respect, Diks and Panchenko's modification seems to fulfil its role.

The presented test results in most cases indicate that there is no occurrence of causation of risk between the analyzed instruments. The strongest and most enduring dependencies have been found in the sector APF. For the FFF sector, the temporary consequence of the risk of investing in the listed companies under investigation was short term.

The studies carried out allow us to formulate the following practical conclusions:

1. Price increases of particular shares of the companies may be better predicted, if appropriately delayed price increases of other analysed indices are taken into account.
2. The division of the WSE-listed agro-food sector into a linear sector with significant investment risk and a non-linear sector with insignificant investment risk.
3. Skillful size forecasting risks is helping investors to make investment decisions on shares in the agri-food sector.
4. The results obtained suggest a need for detailed research in this area.

5. Consideration of using non-linear specifications for the models used in capital markets.

The presented causality testing results refer to earlier studies concerning the use of stock exchange indices as additional variables improving the quality of models and daily quotation forecasts for equities prices. The results of the queries are not entirely exhaustive. A similar analysis would be worth analysing other sectors of the Warsaw Stock Exchange, which would provide a comprehensive picture of the risk causal relationships on the domestic capital market. In addition, the analysis could also be carried out for short positions for different levels of value-at-risk tolerance. Further testing is also indicated by detailing the conditions under which the number of variable delays depends. This should be especially true for the Diks - Panchenko test's, where the results depend on this number. The impact of delays for variables should therefore be examined more closely and the results obtained compared to other methods of detecting causal relationships. The calculations made in this article should provide a basis for further examination.

References

Barnett, L., Barrett, A., Seth, A. (2009). Granger causality and transfer entropy are equivalent for Gaussian variables. *Physical Review Letters,* 103, 238701.

Bauer, D., Maynard, A. (2012). Persistence-robust surplus-lag Granger causality testing. *Journal of Econometrics,* 169, 293-300.

Bruzda, J. (2007). Procesy nieliniowe i zależności długookresowe w ekonomii. Analiza kointegracji nieliniowej, Wydawnictwo Naukowe Uniwersytetu Mikołaja Kopernika, Toruń.

Cartwright, N. (2010). Reply to Steel and Pearl. *Economics and Philosophy*, 26, 87-94.

Cheung, Y.W., Ng, L.K. (1996). A Causality-in-Variance Test and its Application to Financial Market Prices. *Journal of Econometrics*, 72, 33-48.

Diks, C., Panchenko, V. (2006). A new statistics and practical guidelines for nonparametric Granger causality testing. *Journal of Economic Dynamics and Control*, 30, 1647-1669.

Doman, M., Doman, R. (2009). Modelowanie zmienności i ryzyka. Metody ekonometrii finansowej. Wolters Kluwer Polska, Kraków.

Dudek, A. (2008). Analiza związków przyczynowych pomiędzy cenami zbóż paszowych a cenami żywca wieprzowego – zastosowanie modelu wektorowej autoregresji. *Metody Ilościowe w Badaniach Ekonomicznych*, 9.

Dykiel, M., Liszka, M. (2015). Obrót giełdowy artykułami rolno-spożywczymi. Państwowa Wyższa Szkoła Zawodowa w Krośnie, Krosno.

Fałdziński, M., Osińska, M., Zdanowicz, T. (2012). Detecting risk transfer in financial markets using different risk measures. *Central European Journal of Economic Modelling and Econometrics*, 4, 45-64.

Figiel, Sz. (2002). Cenowa efektywność rynku towarowego na przykładzie zbóż w Polsce. Wydawnictwo Uniwersytetu Warmińsko-Mazurskiego, Olsztyn.

Gędek, S. (2009). Analiza powiązań pomiędzy cenami wieprzowiny na rynku polskim i wybranych rynkach krajów Unii Europejskiej. *Roczniki Naukowe SERiA*, 11(3), 92-96.

Gędek, S. (2010). Analiza współzależności cen produktów rolnych. *Roczniki Nauk Rolniczych, Seria G*, 97(3), 88-98.

Granger, C.W.J., Maasoumi, E., Racine, J. (2004). A Dependence Metric for Possibly Nonlinear Processes. *Journal of Time Series Analysis*, 25, 649-669.

Granger, C.W.J., Teräsvirta, T. (1993). Modelling Nonlinear Economic Relationships. Oxford University Press, Oksford.

Hamulczuk, M., Klimkowski, C. (2011). Powiązania między cenami ropy a cenami pszenicy w Polsce. *Roczniki Nauk Rolniczych, Seria G*, 98(3), 176-190.

Hiemstra, C., Jones, J.D. (1994). Testing for linear and nonlinear Granger causality in the stock price volume relation. *Journal of Finance*, 49(5) 1639-1664.

Hlaváčkova-Schindler, K., Paluš, M., Vejmelka, M., Bhattacharya, J. (2007). Causality detection based on information-theoretic approaches in time series analysis. *Physics Reports*, 441, 1-46.

Hong, Y. (2001). A Test for Volatility Spillover with Application to Exchange Rates. *Journal of Econometrics*, 103, 183-224.
Hong, Y., Liu, Y., Wang, S. (2009). Granger Causality in Risk and Detection of Extreme Risk Spillover between Financial Markets. *Journal of Econometrics*, 150, 271-287.
Hoover, K.D. (2001). Causality in Macroeconomics. Cambridge University Press, Cambridge.
Krawiec, M. (2012). Testing the Granger causality for commodity mutual funds in Poland and commodity prices. *Quantitative Methods in Econometrics*, 13(2), 84-95.
Krawiec, M. (2013). Badanie przyczynowości w sensie Grangera na rynku zbóż w Polsce w latach 2007-2011. Szkoła Główna Gospodarstwa Wiejskiego w Warszawie, Warszawa.
Łęt, B. (2014). Badanie przyczynowości w sensie Grangera w ryzyku pomiędzy akcjami z wybranych sektorów GPW w Warszawie. Uniwersytet Ekonomiczny w Poznaniu, Poznań.
Misiuk, A.B., Zajkowska, O. (2010). Does simultaneous investing on different stock markets allow to diversify risk? The cointegration analysis with main focus on Warsaw Stock Exchange. *Quantitative Methods of Economics*, 11, 118-127.
Orzeszko, W., Osińska, M. (2007). Analiza przyczynowości w zakresie zależności nieliniowych. Implikacje finansowe. *Zeszyty Naukowe Uniwersytetu Szczecińskiego. Finanse. Rynki finansowe. Ubezpieczenia*, 6, 151-165.
Osińska, M. (2008). Ekonometryczna analiza zależności przyczynowych. Wydawnictwo Naukowe UMK, Toruń.
Osińska, M. (2011). On the Interpretation of Causality in Granger's Sense. *Dynamic Econometric Models*, 11, 129-139.
Pearl, J. (2000). Causality: Models, Reasoning and Inference. Cambridge University Press, Cambridge.
Rembeza, J. (2009). Powiązania pomiędzy cenami produktów rolnych w Polsce i krajach UE. *Zeszyty Naukowe SGGW Problemy Rolnictwa Światowego*, 7, 111-119.
Rembeza, J., Chotkowski, J. (2010). Powiązania cen pomiędzy małymi rynkami – przykład z rynku ziemniaka. *Roczniki Naukowe SERiA*, 12(4), 298-301.
Rembeza, J. (2010). Transmisja cen w gospodarce polskiej. Wydawnictwo Uczelniane Politechniki Koszalińskiej, Koszalin.
Syczewska, E.M., Struzik, Z.R. (2014). Granger causality and transfer entropy for financial returns. 7 Sympozjum FENS, Lublin.
Tłuczak, A. (2011). Wpływ cen skupu żywca na ceny detaliczne mięsa. *Metody Ilościowe w Badaniach Ekonomicznych*, 12(2), 373-380.
Toda, H.Y., Yamamoto, T. (1995) Statistical inference in vector autoregressions with possibly integrated processes. *Journal of Econometrics*, 66, 225-250.