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SEASONALITY OF WHEAT PRICES IN POLAND AND THE UNITED STATES

Abstract. Seasonality is a phenomenon typical of agricultural markets, but its scale may differ between products. The agricultural production cycle affects the activity of units serving agriculture and fields that benefit from its production. For the investor, seasonality may be an opportunity to generate profits. The purpose of this study is to assess the seasonal distribution of wheat price fluctuations in Poland and the US in 2000–2017, and to examine the strength of the relation between the time series analyzed. The initial analysis started with a description of general price trends. The next step was the assessment of correlation between prices and relative increments in Poland and the US. The seasonal distribution of wheat price fluctuations in Poland and the US was studied using the Census X12 procedure. A multiplicative model was used. The findings reveal a connection between Polish and US markets. Based on the result of the Granger causality test, Poland appears as a recipient of global price signals. The research also confirms the occurrence of seasonal fluctuations. In Poland, seasonal fluctuations in wheat prices are significantly stronger than seasonal fluctuations in wheat contracts on the Chicago Board of Trade (CBOT) and in US export prices (GULF). The analyses of seasonal indexes led to the following discoveries, in particular: a one-month delay of seasonal deviations of wheat price at GULF in relation to seasonal deviations of CBOT wheat prices; and a 3-month delay in seasonal deviations of wheat price in Poland in relation to seasonal deviations of wheat price at GULF. In addition, seasonal behavior in Poland is more stable than in the US. These findings can be used for investment and speculation purposes.

Keywords: seasonal fluctuations, prices, wheat, causality

INTRODUCTION

Agriculture is a material production sector affected by the strongest seasonal variations caused directly by the fact that the duration of production processes depends on changing climatic conditions. Agriculture faces many threats while also enjoying favorable conditions driven by environmental, weather, economic and even political aspects. A classic example of such a risk factor are weather conditions that can either destroy the entire production or contribute to above-average and unexpected results. The seasonality of agricultural production is also related to environmental and weather conditions. The annual schedule of work can vary greatly between agricultural activities. During a year, significant differences also exist between the outcomes these activities,

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i.e. products intended for sale. A classic example of this situation is the production of cereals or an even more extensive plant production. Weather factors have a smaller impact on animal production, which is why its seasonal fluctuations will be smaller. However, a certain degree of dependence exists in this case, too, because part of the crop output is used in animal production. Hence, an indirect impact of seasonality is experienced in the milk market, for example (Iwan, 2005). Physical impacts of the seasons, including such phenomena as atmospheric changes and changes in light intensity, temperature, pressure and rainfall during the year, are referred to as exogenous, non-economic factors (Sobczyk, 1976).

Meanwhile, the demand side (consumers, the processing industry and others) shows that demand for agricultural products is more evenly distributed over time. Therefore, there will often be a gap between supply and demand. According to market rules, the gap will be bridged by prices. As a consequence of the supply and demand mismatch, agricultural prices fluctuate considerably. Also, in order to stagger the supply, operators need to store their produce and develop food processing and preservation processes.

On the agricultural supply side, three main drivers of price changes are identified: extreme weather events; slowdown in cereal production growth; and rising oil prices and their consequences for the real economy (Flassbeck et al., 2011). Although inventories are linked to both demand and supply, they play a key role in the supply of agricultural products, because the flexibility of supply of agricultural products is low due to the seasonal nature of production (Emback and Raquet 2011).

Considering the above, the goal of this research is to assess seasonal fluctuations in wheat prices in Poland and the US. An analysis was carried out of 2000–2017 time series of wheat prices in both countries. In line with the objective of the study, monthly data was analyzed. Data on Polish prices (purchase price in PLN per dt) was retrieved from Statistics Poland. In the American market, the analysis focused on the price of futures contracts from the Chicago Board of Trade (CBOT). The time series analyzed consisted of prices of contracts with the nearest maturity date, listed in cents per bushel. Also used were wheat prices offered for export in Gulfport with immediate delivery or a one-month delivery time. The information was obtained from the US Department of Agriculture (USDA) and is quoted in dollars per ton.

SEASONALITY IN AGRICULTURAL MARKETS

Seasonal variability affects many economic phenomena. It can be defined as a systematic—though not necessarily regular and unchanging—movement during the year (Hylleberg, 1992). The sources of seasonal fluctuations are diverse, and generally result from the changing supply and demand conditions throughout the year (Gill, 1991). Well-known examples of seasonal fluctuations include changes in prices of agricultural products. Many of them are characterized by specific, conditioned climatic factors of production cycles. As a consequence, peak supply coincides with the harvest season. Keeping the products in the following months requires additional storage costs.

Seasonality is a phenomenon typical of all agricultural markets, but its scale may differ between products (Canova and Hansen, 1995). The analysis of seasonality in purchasing cereals shows that peak supply of cereals to the market occurs right after the harvest. Animal farming is also clearly dependent upon the seasons, including the production of meat, milk or eggs. In Poland, the purchase of potatoes is even more severely affected by seasonality as ca. 50% of the total supply arrives in October. The agricultural production cycle affects the activity of units serving agriculture and sectors that benefit from its production. The agricultural sector has a greater demand for machinery, fertilizers and transport services during spring and fall (Sobczyk, 1976).

The results of the analyses reveal a high seasonality of potato prices which vary strongly over time. The general trend was a clear decline in seasonal price fluctuations. It was mainly due to a smaller number of seasonal price increases during summer and to the absence of seasonal price drops during spring. These changes may be associated with the introduction of new production and storage technologies, the discontinuation of potato production in a large part of farms, and changes in potato uses (Rembeza, 2015).

Meanwhile, agricultural production faces growing risks because of weather variability, the seasonal cycle of farming activities and the related volatility of food prices. Under such conditions, it is important to take appropriate planning measures and analyze various development scenarios. Considering that the combination of key trends and risks may lead to different future outcomes, the development scenarios for the agricultural sector broaden the perspective and illustrate the consequences of different choices (Nayyar and Dreier, 2017).

Risk management in agricultural production is all the more important since the agricultural sector influences other parts of the economy within a country. Agricultural futures contracts allow to effectively set future prices, plan production operations, manage the risks, and minimize the effects of production and consumption seasonality. This means that investments in agricultural production can prove to be efficient (Cetinkaya, 2006). The contracts can contribute to reducing the uncertainty of the agricultural market, and can become an important risk reduction measure for industries that rely on products from the agricultural sector (Erbay, 2007).

Because today's futures markets are so important in providing information to real markets, they become the basic mechanism for spot price formation, especially with respect to seasonal agricultural products whose sales are spread over time (Staritz and Girardi 2012). The studies on the relation between spot futures in the maize and soy markets are widely known. They clearly found that maize and soy futures are used as a benchmark for spot prices, and that changes in forward prices usually lead to changes in spot prices (Baldi et al., 2010).

METHOD OF ANALYSIS

The data series used in this study differ in units of measurement. However, this is not a problem in the assessment of trends. Therefore, the initial analysis started with the description of trends and general price formation patterns in 2000–2017. Then, relative increments were determined. Since they are denominated values, they can be compared with numerical statistics. Also, quartiles and standard deviations were used in the study. The intensity of changes over time was determined. The analysis of correlation of prices and relative increments between Poland and the US was completed as part of preliminary research. This study allowed to assess the strength of interrelation between the time series analyzed.

The main part of the study, focused on assessing the distribution of seasonal fluctuations in wheat prices in Poland and the US, started by checking whether the time series is stationary (Dickey and Fuller, 1979). This test precedes the Granger causality test (Granger, 1969) carried out for price series and series of relative increments. According to the theory, the levels of significance delivered by the Granger test are reliable for stationary series and only approximate for non-stationary series (Kusideł, 2000). This study tested causality between prices (and relative price increases) in the Polish and in US (CBOT and GULF) markets. The causality test allows to assess the direction of price signals flowing between the markets. The model subject to evaluation for causality was as follows:

$$x_t = a_1 + a_{1.1}x_{t-1} + a_{1.2}x_{t-2} + b_{1.1}y_{t-1} + b_{1.2}y_{t-2},$$
$$y_t = a_2 + a_{2.1}x_{t-1} + a_{2.2}x_{t-2} + b_{2.1}y_{t-1} + b_{2.2}y_{t-2}.$$

where:

a_i, $a_{i.j}$: structural parameters;

y_t, x_t: wheat prices (or relative price increments) in the Polish and US market.

The distribution of seasonal variations was assessed using the Census X12 procedure (Fischer, 1995; Findley et al., 1998). A multiplicative model was used which allows to compare the strength and distribution of seasonal variations between the time series analyzed. The seasonal component and the irregular component isolated from the time series are presented graphically. They were determined based on standard deviations. In addition, seasonality indices were calculated based on the seasonal component as arithmetic means for homonymous periods, and were assessed for significance. The isolated seasonal ingredient was checked for seasonality using the Test for the Presence of Seasonality Assuming Stability, the Non-Parametric Test for the Presence of Seasonality Assuming Stability, and the Moving Seasonality Test (Hamulczuk, 2011). The results provided a basis for comparing the strength and distribution of seasonal fluctuations of wheat prices between Poland and the US.

DATA ANALYSIS

At CBOT and GULF, wheat contracts are quoted in cents per bushel and in USD per ton, respectively. A series of prices for wheat contracts on the CBOT exchange was created from a series of individual contracts by noting the price of the contract ending the fastest. Presumably, that price series would be closest to the range of cash prices. Actually, despite different metric units, CBOT and GULF price series are very similar in their waveforms. In 2000–2007, prices grew slowly yet consistently.

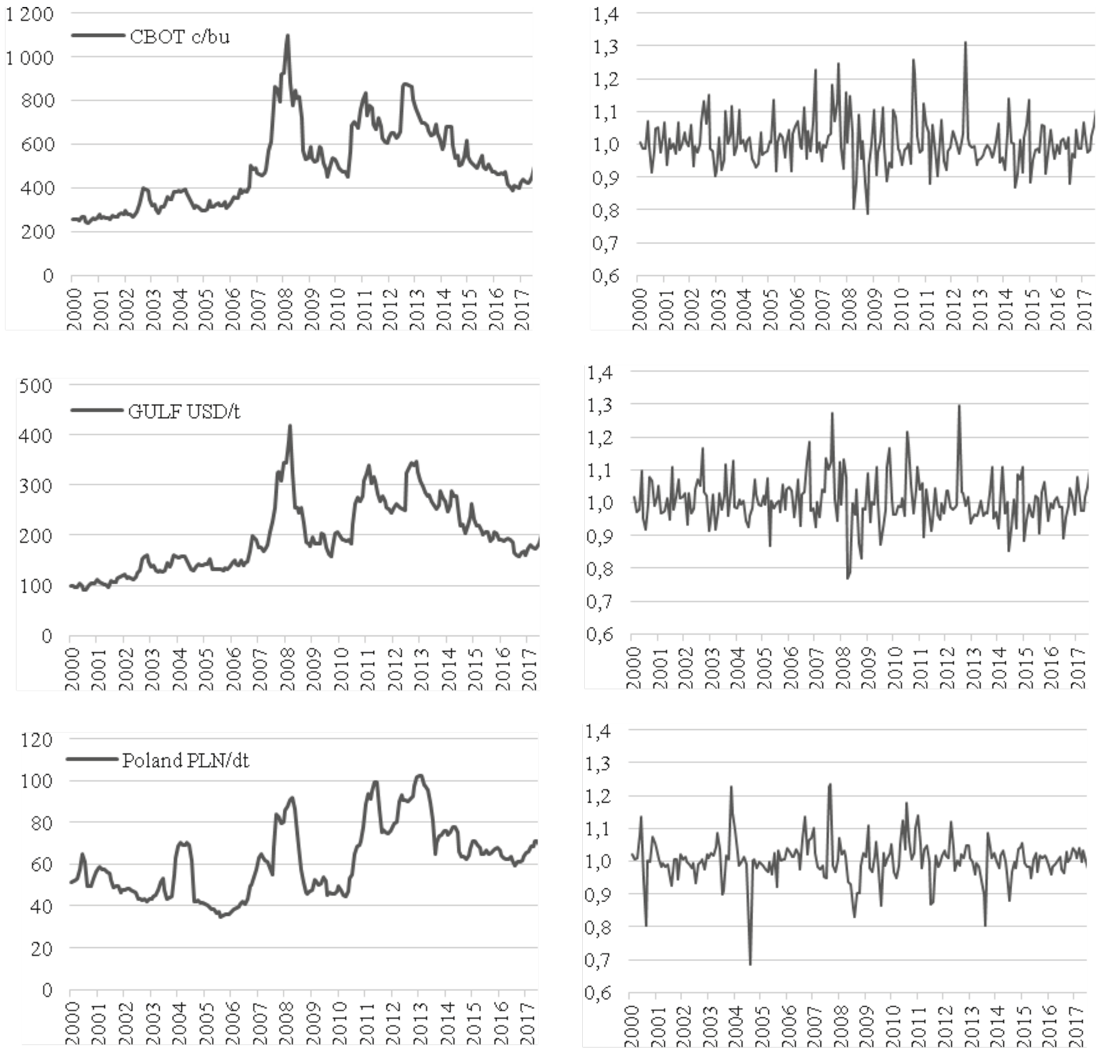

Fig. 1. Time series of wheat prices and increases in wheat prices
Source: own study based on data from CBOT, USDA and the Central Statistical Office.

The highest level ever was reached in 2008, after a sharp rise in prices. Following this, the prices dropped equally fast. The next increase (reaching its peak in 2012) was followed by a slow decline in prices. The level recorded at the turn of 2006/2007 was seen again in 2017.

Poland is in a slightly different situation as it witnessed a drop in prices in early 2000s. This was followed by a short-term increase in 2004 and rapid growth in 2007–2008. However, the 2008 peak was not the highest level ever (recorded in 2013). In recent years, similarly as in CBOT and GULF, prices have stabilized slightly above the historical average.

The series of price increments allows to identify periods of increased volatility which coincide with rapid rises and drops in prices. For CBOT and GULF, this was primarily the case in late 2007/early 2008, in 2010 and in 2011. In Poland, this happened in late 2003/early 2004, in 2007 and in 2013. In general, price volatility in Poland is lower than in the US (Table 1). The quartile spread (q25-q75) for wheat prices in Poland stood at 0.9808–1.0260, compared to 0.9695–1.0357 for CBOT and 0.9662–1.0384 for GULF. Also, standard deviation of price increments in Poland (0.0641) was clearly lower than in the US (0.0732 for CBOT and 0.0716 for GULF).

Table 1. Descriptive characteristics of the series of wheat price increments

	d(CBOT)	d(GULF)	d(Poland)
min	0.7887	0.7708	0.6860
q25	0.9695	0.9662	0.9805
q50	0.9946	0.9964	1.0057
q75	1.0357	1.0384	1.0260
max	1.3125	1.2946	1.2340
std. dev.	0.0732	0.0716	0.0641

Source: own calculations based on data from CBOT, Quandl and the Central Statistical Office.

Table 2. Correlation between the series of wheat prices and the series of wheat price increments

Poland	CBOT	GULF
level	0.7732	0.8107
1st difference	0.2829	0.2858

Source: own calculations based on data from CBOT, Quandl and the Central Statistical Office.

Note that despite some differences in price trends between Poland and the US, the correlation is quite strong: the coefficients are 0.7732 between the prices in Poland and CBOT futures contracts, and 0.8107 between the prices in Poland and export prices in Gulfport. The above shows that long-term trends are somehow similar, although they do not testify to cointegration. The relationship between increments is positive, too (though weaker): the coefficients are 0.2829 between wheat prices in Poland and CBOT futures contracts, and 0.2858 between wheat prices in Poland and GULF export prices.

Findings from the correlation analysis suggest there is a connection between the Polish and the US market. Further research is required to describe this relationship, including the analysis of causality, which will be done below.

EVALUATION OF SEASONAL FLUCTUATIONS IN WHEAT PRICES IN POLAND AND THE US

The overall result of the Granger causality test (Table 3) shows that prices (and price increments) in the US are the cause of prices (and price increments) recorded in Poland (all levels of significance are $p < 0.005$). No opposite causal relationship (signal from Polish prices and price increments) was found at any level of significance ($p > 0.25$). This could suggest that Poland appears as a recipient of global price signals.

Figure 2 shows the seasonal component and the irregular component of the time series of wheat prices. These components differ quite clearly between individual wheat prices. In general, the seasonal component of wheat prices in Poland is the strongest one while the irregular component is the weakest one. Compared to CBOT and GULF, Poland exhibited the strongest seasonal fluctuations. This is also confirmed by high levels of test statistics (Table 4): stability test $F = 26.577$; nonparametric stability test $KW = 140.87$; mobile seasonality test $F = 3.596$. For the CBOT and GULF time series, these statistics are clearly lower. The seasonal component for CBOT is unstable over time. Conversely, it is stable at the GULF, although the chart clearly shows that seasonal fluctuations have weakened in recent years.

The change in the seasonal fluctuation pattern shown in Figure 2 (stronger fluctuations in early 2000s, weaker fluctuations over the last decade—particularly noticeable in the CBOT futures market) may be caused by the inflow of speculative capital into the stock market after the

Table 3. Pairwise Granger Causality Tests

X → Y	F-Statistic	Prob.	d(X) → d(Y)	F-Statistic	Prob.
Poland → CBOT	0.3741	0.6884	d(Poland) → d(CBOT)	1.3015	0.2743
CBOT → Poland	8.1992	0.0004	d(CBOT) → d(Poland)	5.4617	0.0049
Poland → GULF	0.0217	0.9785	d(Poland) → d(GULF)	1.3489	0.2618
GULF → Poland	12.9107	0.0000	d(GULF) → d(Poland)	8.5420	0.0003

Explanations: Null Hypothesis: X does not Granger Cause Y (X → Y)
Source: own calculations.

Table 4. Seasonality tests

Seasonality tests	CBOT		GULF		Poland	
Test for the Presence of Seasonality Assuming Stability	F-value	prob.	F-value	prob.	F-value	prob.
	1.572	p > 0.1	8.713	p < 0.1	26.577	p < 0.1
Nonparametric Test for the Presence of Seasonality Assuming Stability	KW Stat	prob.	KW Stat	prob.	KW Stat	prob.
	17.282	0.0998	73.924	0.000	140.87	0.000
Moving Seasonality Test	F-value	prob.	F-value	prob.	F-value	prob.
	2.104	p < 0.01	1.919	p < 0.05	3.596	p < 0.01

Source: own calculations.

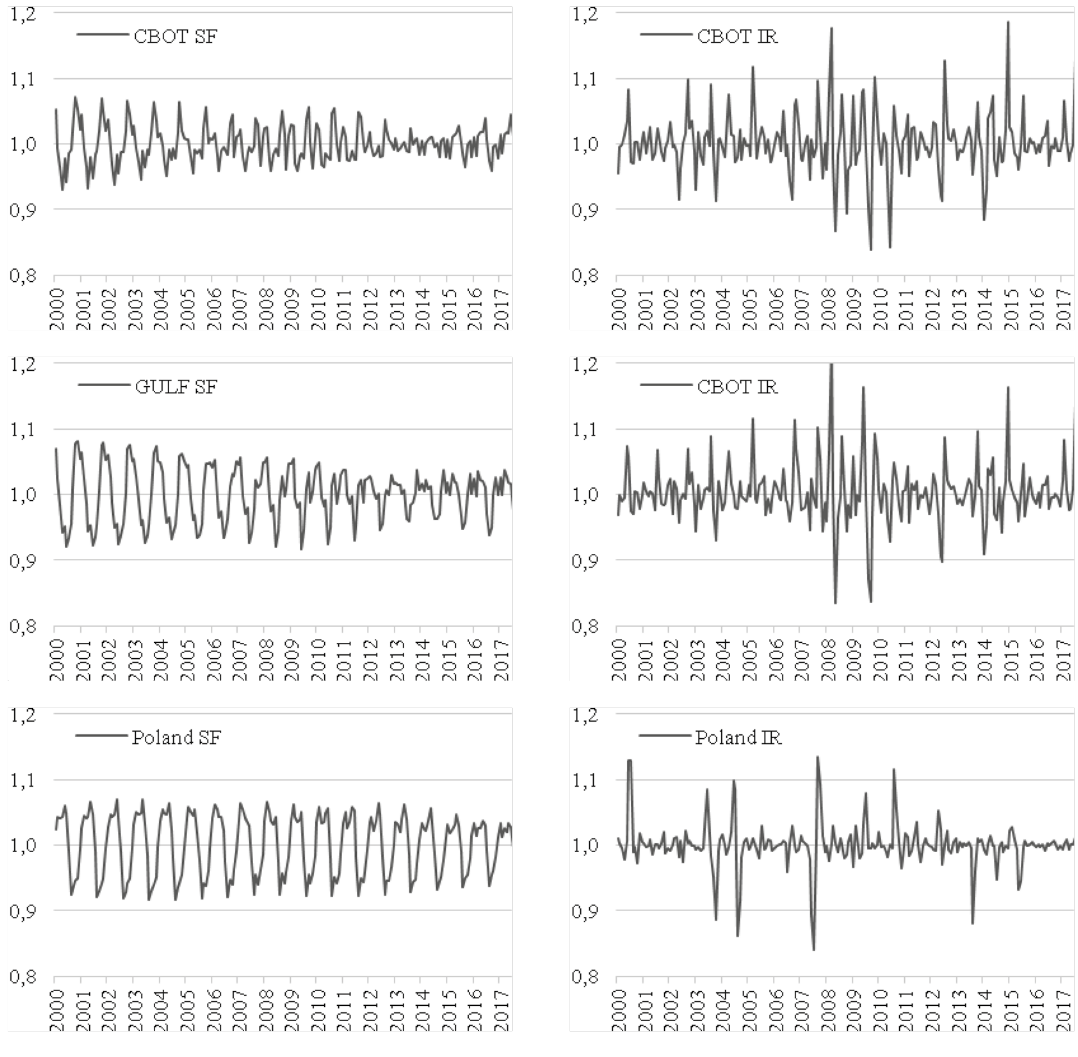

Fig. 2. Seasonal and irregular components in the wheat price time series
Source: own study.

2008/2009 crisis. The literature on the subject suggests that agricultural stock exchange markets have undergone financialization (Mayer, 2009). Hence, it can be assumed that an inflow of above-average amounts of capital will smooth seasonal fluctuations while strengthening random fluctuations, which is consistent with the observations.

Standard deviation of the irregular component for both CBOT and GULF was 0.0461. These are quite significant figures given that the standard deviation of the seasonal component was 0.0271 for CBOT and 0.0399 for GULF. For Poland, the standard deviation of the irregular component was 0.0336, i.e. much less than the standard deviation of the seasonal component (0.0452). This suggests that seasonal behavior is more predictable in Poland than in the US.

Seasonal indices were calculated as arithmetic means of seasonal components of homonymous periods (Table 5). Standard deviations of these indices are much smaller in Poland than at CBOT and GULF. This is an obvious consequence of the above findings. In addition, significant differences in their distribution over time can be observed.

At CBOT, upward deviations from the trend were observed in January and February and from August to December but were statistically significantly different from 1 only in January, September and October. Conversely, downward deviations were observed from March to July and each proved to be significant. The strongest upward deviation was observed in January (2.13%) and October (2.72%), whereas the strongest downward deviation was experienced in April (-2.96%).

In Gulfport, upward deviations from the trend were observed from January to March and in November and December. All were statistically significant except for March. The largest deviation was recorded in January (4.03%). On the other hand, downward deviations were observed from April to September. All of them were significant except for September. The strongest downward deviations were reported in June (–5.37%) and July (–5.09%). It follows that although seasonal deviations at CBOT are weaker than at GULF, they occur ca. 1 month in advance. This information is important for the US cash market.

In Poland, upward deviations from the trend were observed from January to June, whereas downward deviations were recorded from July to December. All were statistically significant except for December. All upward deviations were very strong (ca. 3.4%–5.2%). The largest

Table 5. Seasonality indices

Month	CBOT		GULF		Poland	
	indices	std. dev.	indices	std. dev.	indices	std. dev.
Jan	1.0213*	0.0137	1.0403*	0.0157	1.0340*	0.0045
Feb	1.0007	0.0157	1.0288*	0.0196	1.0445*	0.0167
Mar	0.9828*	0.0158	1.0030	0.0166	1.0375*	0.0119
Apr	0.9704*	0.0285	0.9796*	0.0261	1.0383*	0.0073
May	0.9941*	0.0126	0.9857*	0.0229	1.0518*	0.0127
Jun	0.9883*	0.0275	0.9463*	0.0321	1.0370*	0.0112
Jul	0.9890*	0.0091	0.9491*	0.0120	0.9832*	0.0063
Aug	1.0015	0.0254	0.9701*	0.0250	0.9251*	0.0066
Sep	1.0151*	0.0305	0.9997	0.0261	0.9452*	0.0098
Oct	1.0272*	0.0293	1.0222*	0.0327	0.9456*	0.0072
Nov	1.0030	0.0281	1.0383*	0.0247	0.9631*	0.0113
Dec	1.0010	0.0147	1.0313*	0.0214	0.9976	0.0100

Explanations: * indices significantly different from 1 at $p < 0.05$ were identified.
Source: own calculations.

downward deviation was reported in August (–7.49%). It turns out that seasonal deviations of wheat prices from the GULF port sell out seasonal deviations of wheat prices in Poland by about 3 months.

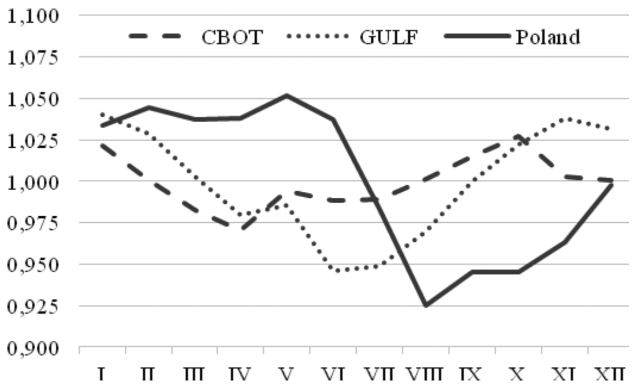

Fig. 3. Seasonality indices.
Source: own study.

Figure 3 shows the values of seasonal indexes calculated. It is a graphical illustration of results specified in Table 5. As can be observed, single fluctuations are particularly strong in the seasonal indices chart and – as already mentioned – are clearly stronger in Poland than in the US. The analyses of seasonal indexes led to the following discoveries, in particular: a one-month delay of seasonal deviations of wheat price at GULF in relation to seasonal deviations of CBOT wheat prices; and a 3-month delay in seasonal deviations of wheat price in Poland in relation to seasonal deviations of wheat price at GULF.

SUMMARY

The production of cereals, including wheat, is of strategic importance to the functioning of both the food economy and the whole national economy. As a basic agricultural produce, cereals are a product for the primary and, afterwards for the secondary processing industry. In recent years, the role of industrial grain processing and use for non-food purposes has increased, primarily in the production of biofuels. Cereals are of strategic importance and are considered to be the key agri-food product decisive for national food security. Hence, fluctuations in cereal supply considerably impact both the agriculture and the nationwide economy.

This research focused on one aspect of product price formation in agricultural markets, i.e. on the analysis of how seasonal price fluctuations are distributed in Poland and the US. Although these are very distant markets, the correlation coefficients calculated in this study are significant. Moreover, the causality test indicates that wheat prices in Poland are formed in response to price changes in the US market. This means that earlier prices in the US market can be used to forecast prices in the Polish market.

Research shows that seasonal fluctuations in Poland are significantly stronger than those recorded at CBOT and in Gulfport. Since no agricultural futures market exists in Poland, investors active in the Polish wheat market are producers, intermediaries and processors. Meanwhile, futures market speculators are an important group in the US, and their activity results in smoothing seasonal fluctuations and in amplifying accidental fluctuations.

Another important finding from this research is that the prices in the Polish market respond with a delay to the developments in the US market. Seasonal variations observed in Poland are lagged in relation to seasonal fluctuations in the US. This is consistent with the results of the causality test.

In this case, the Polish market appears to be the recipient of price signals from the US market. It is pointed out that price signals flowing from a larger economy to a smaller one are stronger than those flowing in the opposite direction. The size of economies, along with the distance between them, determine the importance and intensity of price exchange and transmission mechanisms. This is confirmed by the fact that Poland is considered a small country in the global economic system.

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SEZONOWOŚĆ CEN PSZENICY W POLSCE I STANACH ZJEDNOCZONYCH

Abstrakt. Sezonowość jest zjawiskiem typowym dla rynków rolnych, jednak jej skala może być odmienna dla poszczególnych produktów. Cykl produkcji rolnej wpływa na działalność jednostek obsługujących rolnictwo oraz dziedzin, które korzystają z jego produkcji. Dla inwestora wykorzystanie zjawiska sezonowości może być sposobnością do generowania zysków. Celem opracowania są oceny rozkładu wahań sezonowych cen pszenicy w Polsce i USA w latach 2000–2017 oraz siły powiązania analizowanych szeregów czasowych. Analizę wstępną rozpoczęto od opisu ogólnego kształtowania cen, następnie przeprowadzono badanie korelacji cen i przyrostów względnych pomiędzy Polską a USA. Właściwe badania odnoszące się do oceny rozkładu wahań sezonowych cen pszenicy w Polsce i USA przeprowadzono przy użyciu procedury Census X12. Zastosowano tutaj model multiplikatywny. Uzyskane rezultaty badań świadczą o powiązaniu rynków polskiego i amerykańskiego. Na podstawie wyniku testu przyczynowości Grangera, Polska jawi się jako biorca cen światowych. Przeprowadzone badania potwierdzają także występowanie wahań sezonowych. Wahania sezonowe cen pszenicy w Polsce są istotnie silniejsze niż wahania sezonowe notowań kontraktów na pszenicę na giełdzie

Chicago Board of Trade (CBOT) oraz wahania sezonowe amerykańskich cen eksportowych (GULF). Z otrzymanych indeksów sezonowych, w szczególności zaobserwować można jednomiesięczne opóźnienie odchyleń sezonowych cen pszenicy w porcie GULF w stosunku do odchyleń sezonowych cen pszenicy CBOT, a także trzymiesięczne opóźnienie odchyleń sezonowych cen pszenicy w Polsce w stosunku do odchyleń sezonowych cen pszenicy w porcie GULF. Dodatkowo stabilność zachowania sezonowego w Polsce jest większa niż w USA. Wyniki te mogą być wykorzystane w celach inwestycyjnych i spekulacyjnych.

Słowa kluczowe: wahania sezonowe, ceny, pszenica, przyczynowość