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## RYE PRICE VARIABILITY IN POLAND BETWEEN 2010 AND 2018<sup>1</sup>

Key words: price variability, seasonal fluctuation, time series decomposition

**ABSTRACT.** In the paper, the range of rye price variability was determined and a decomposition of a time series of prices was carried out, distinguishing seasonal, cyclical and irregular fluctuations. The rye market is a market of a product produced seasonally but with a storage period longer than one season, which influences seasonal changes of prices, on which economic changes overlap. The research material consists of prices of rye in monthly graduation for the years 2010-2018, from the Integrated System of Agricultural Market Information. In the analyzed period, the nominal price of rye more than doubled from 327 PLN/t in January 2010 to 719 PLN/t in December 2018. The coefficient of variability of rye prices ranged from 4.0% to 27.2%. The decomposition of the time series of prices indicates seasonal, cyclical and irregular fluctuations. The amplitude of seasonal fluctuations was 14% on average, the highest prices were in June (105%) and the lowest in August (91%). Cyclical changes averaged 71.2% per year, seasonal changes 17.9% and irregular changes 10.9% of overall rye price variation. The production of rye is steadily falling both in the world and Poland.

### INTRODUCTION

In the free market economy, price variability is natural and results from the functioning of market mechanisms. Agricultural markets are characterized by significant price volatility related, inter alia, to biological conditions of agricultural production strongly dependent on weather conditions. The rye market is a market of a product produced seasonally but with a storage period longer than one season, which influences seasonal changes of prices, on which economic changes overlap. Price risk, i.e. the risk of adverse price changes, results from the variability of demand and supply. The cereals market is characterised by a relatively high price elasticity of supply and a relatively low price elasticity of demand [Rembisz 2003]. Not every price change indicates a risk. Seasonal changes that occur regularly can be taken into account in the calculation of production profitability. Unexpected changes that are difficult to explain should be treated as a sign of risk [Hamulczuk, Rembisz 2008]. Multiannual price risk management, knowledge of

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mechanisms influencing price volatility and the ability to decompose general volatility into seasonal, cyclical and irregular fluctuations are important for both producers and consumers and play an important role in the price risk management process.

Rye (*Secale L.*) is a type of plant of the wheat grass (*Poaceae*) family. It originates from Central Asia and has around 10 different species, the most important of which, in economic terms, is common rye. Resistant to a harsh climate and poor soil conditions, the plant has also spread throughout Europe. According to historical sources, rye was cultivated in Central and Northern Europe after 1000 BC and, in Poland, only at the beginning of the so-called Roman period. In the era of the first Piasts, farmers were familiar with winter rye in addition to wheat, barley, millet and oat.

Rye has a number of properties that make it ideal for growing in temperate climates. It has a well-developed root system, low water requirements, good tolerance to acidic soil and high frost resistance, and does not require soils with high physico-chemical properties. In Poland, traditional population varieties as well as synthetic and hybrid varieties are grown, such as: Dańkowskie Diament, which is resistant to disease, has a high protein content and average fertility, Palazzo F1 (hybrid), which, apart from lower resistance, has a low protein content and good fertility, and Brasetto (hybrid) with poor resistance, low tolerance to acidification of soil and very good fertility. COBORU's Pre-registered Varietal and Agricultural Experimental Station recommends special varieties of rye for particular regions of the country. Due to the fact that rye has relatively low soil and water requirements, it occupies a considerable area of cultivation in our country. The winter form itself is present on an area of about 1.5 million ha.

Rye grain is mainly used for animal feed. In addition, this grain is used in the grain and mill industry as a raw material for flour, from which two types of bread are made: light rye (low ash) and dark rye (ash content over 1%). In addition to bread, rye flour, cakes, bran, flakes and rye beer are available for sale.

Good quality rye food is a source of valuable fiber, vitamins and minerals. It is rich in phytoestrogens, has an anti-cancer effect and its high fibre content prevents diseases of the digestive system and provides a feeling of satiation. Rye has many pro-health properties, but contains gluten and rye products should be avoided by people who are allergic to rye.

Today, despite its excellent resistance, rye is becoming less and less economically important in the world – only in Central and Eastern Europe, including Poland, is it still a common bread-making crop that is most suitable for light and weak soils.

The aim of this paper is to determine the range of variability and distinguish fluctuations: irregular, seasonal and cyclical rye prices, in Poland, in the period 2010-2018.

## MATERIAL AND METHODS

The research material was a monthly time series for prices of rye in 2010-2018. The prices came from the Integrated System of Agricultural Market Information [MRiRW 2019], whereas the level of rye production in Poland was obtained from the FAOSTAT Database [FAOSTAT 2019].

The range of price variability in a year was presented with a variability coefficient, minimum value and maximum value (interval), maximum monthly change in price (increase or decrease) and the change in price indicator (in %). The analysis of the price variability for rye was conducted with a price time series decomposition. A time series includes the following elements [Dittmann 2008]:

1. Developmental tendency – trend ( $T$ ) – it shows the long-term tendency for one-way changes (increase or decrease) of the price. It is understood as the effect of the influence of a constant set of factors.
2. Cyclic fluctuations ( $C$ ) – they are formed as long-term, rhythmically repetitive price fluctuations around the developmental tendency in time intervals longer than one year.
3. Seasonal fluctuations ( $S$ ) – are price fluctuations of the observed variable (price) around the developmental tendency and repeat in a time interval not longer than one year.
4. Random fluctuations – random element – ( $I$ ).

To describe the time series for rye prices, a multiplicative model was used in the form of the following formula [Stańko 2013]:

$$Y_t = T_t C_t S_t I_t$$

where:  $Y_t$  – livestock price in time  $t$ ,  $T_t C_t$  – long-term trend and cyclical fluctuations,  $S_t$  – seasonal fluctuations,  $I_t$  – incidental fluctuations.

The Census II/X11 method [Idzik 2009] was used to determine seasonality indices. An advantage of the Census II/X11 method is, among others, the possibility of estimating seasonal fluctuations for each year separately, which allows to analyze possible changes in seasonality patterns over longer periods of time. In order to check the significance of seasonality indices, the analysis of variance for the values of indices in individual months was performed using the F test.

The cyclical and trend were separated by the Hodrick-Prescott filter, which extracts a stochastic trend that changes smoothly over time from the time series [Hodrick, Prescott 1997]. The Hodrick-Prescott method consists of presenting the value of the time series as the sum of the long-term trend and cyclic component:

$$X_t = T_t + C_t$$

where:  $X_t$  – value of the time series,  $T_t$  – value of the long-term trend,  $C_t$  – value of the cyclic component.

The smoothing parameter was set at a level of  $\lambda = 1,600$  due to the quarterly data.

The influence of individual components of the time series, such as seasonality ( $S$ ), incidental fluctuations ( $I$ ) and development trends ( $TC$ ) on the overall variability of prices of broiler livestock was determined depending on the duration of the changes. For this purpose, the share of variance of individual components of the series in the total price variance was analyzed. The calculations were performed using a package of analysis of time series and forecasting included in the Statistica 9.0 program [Kot et al. 2011].

## RESULTS

Over the last few decades, there has been a systematic decline in rye production both in the world and Poland (Figure 1). Rye, in Poland, was traditionally the basic crop in extensive pig rearing and was most closely related to this production. In 1961, the production volume of rye was at a level of 8.36 million tons with the area sown to this crop of 4.88 million ha, which gave a yield of 1.7 tons per hectare. In the following years, the production level oscillated around the linear downward (decreasing) trend, decreasing, on average, by 0.1 million tons annually.

By 2017, the volume of production decreased more than 3 times to 2.67 million tons. The sown area decreased almost 6 times to 0.87 million ha, while production output increased to 3.06 tons/ha. In 2017, the world level of rye production was 13.73 million tons (Table 1). The largest rye producer in the world was Germany (2.74 million tons, which accounted for 19.9% of world production), followed by Poland (2.67 million tons, 19.5%) and Russia (2.55 million tons, 18.5%).

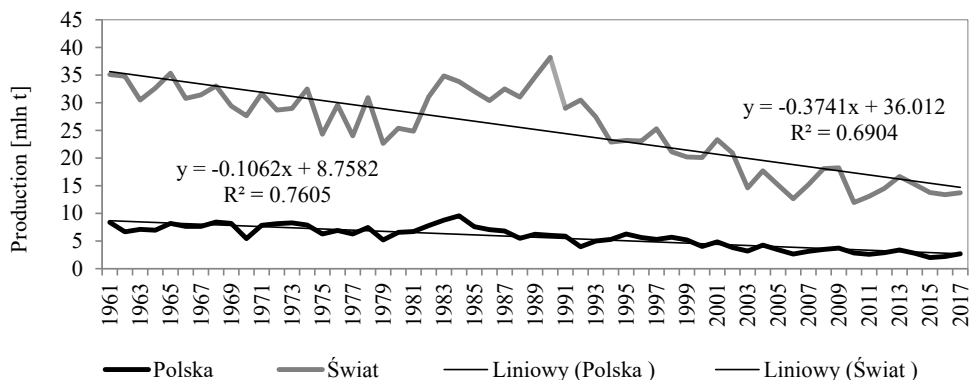


Figure 1. The volume of rye production in Poland compared to world production between 1961-2017  
Source: own study

Table 1. Largest rye producers in the world in 2017

Country	Production		Country	Production	
	thous. t	share [%]*		thous. t	share [%]*
Germany	2,737.4	19.9	Ukraine	507.9	3.7
Poland	2,673.6	19.5	Turkey	320.0	2.3
Russia	2,547.0	18.5	Canada	300.4	2.2
China	1,332.3	9.7	USA	246.3	1.8
Denmark	723.2	5.3	Other	1,676.0	12.2
Belarus	669.8	4.9	Total world	13,733.9	100.0

\* share in world production

Source: own calculations

The price of rye has been subject to considerable fluctuations. Over the last nine years, the price increased more than twice from PLN 327 per ton in January 2010 to PLN 719 per ton in December 2018 (Figure 2, Table 2). The largest monthly drop in prices (-18.4%) took place in 2011, when the price dropped from PLN 760/t in July to PLN 620/t in August. The largest monthly price increase (19.5%) occurred in 2010 when the price rose from PLN 374 per ton in July to PLN 447 per ton in August. The annual price volatility index ranged from 27.2% in 2010 to 4.0% in 2015.

The decomposition of the time series of prices indicates the occurrence of both irregular and seasonal fluctuations, cyclical fluctuations and long-term trends in the analysed period (Figure 3). The stable seasonality test indicated that seasonal fluctuations were statistically highly significant ( $p > 0.00001$ ; test value  $F = 10.7$ ). In the years 2010-2012, the highest prices were noted between February and May, while in the following years the highest prices were in June (105%), and the lowest in August (91%), with an average amplitude of seasonal fluctuations of 14% (Figure 4).

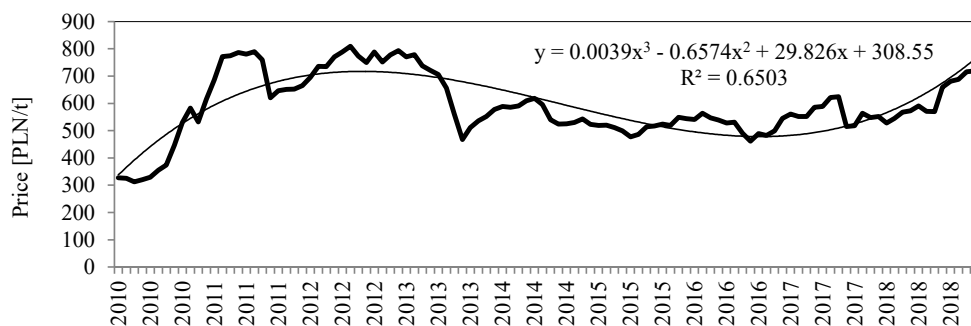


Figure 2. Nominal prices of rye in Poland 2010-2018

Source: own study

Table 2. Variability of rye prices in 2010-2018

Year	Average	min	max	Variability coefficient [%]	Max monthly %		Index of change	
	PLN/kg				decrease	increase	yearly	2010 = 1
2010	421	312	615	27.2	-8.7	19.5	1.9	1.0
2011	715	620	789	9.3	-18.4	12.5	1.0	1.7
2012	764	695	809	4.2	-4.6	5.9	1.1	1.8
2013	631	467	778	17.3	-16.8	9.4	0.7	1.5
2014	565	523	618	6.5	-9.4	3.2	0.9	1.3
2015	515	477	549	4.0	-4.4	5.8	1.0	1.2
2016	518	461	564	6.2	-7.7	9.2	1.0	1.2
2017	565	515	624	6.2	-17.5	8.8	1.0	1.3
2018	617	528	719	11.3	-4.3	15.7	1.4	1.5

Source: own calculations

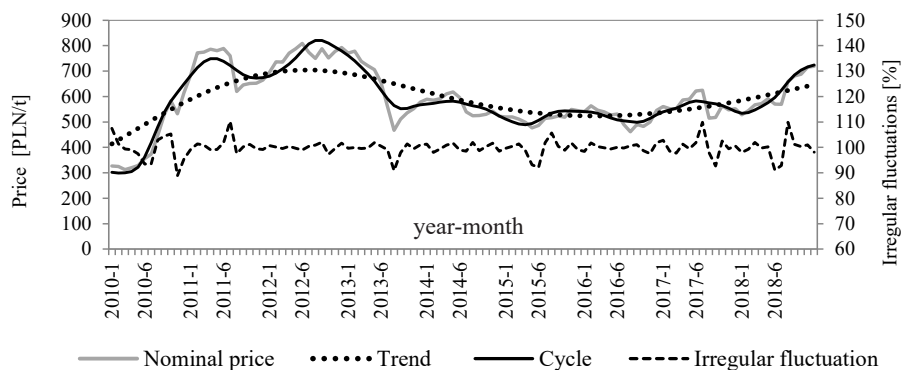


Figure 3. Decomposition of the time series for rye prices between 2010 and 2018

Source: own study

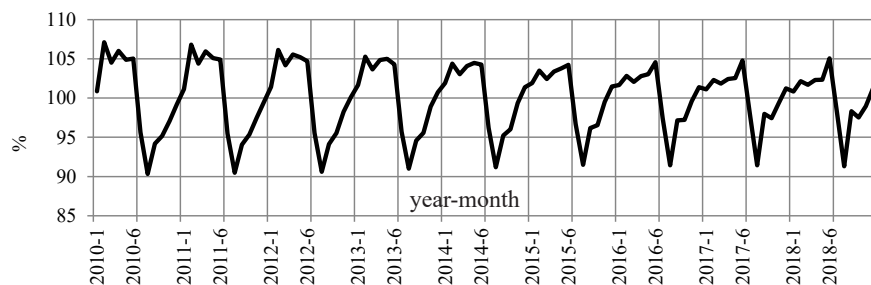


Figure 4. Seasonal fluctuations in rye prices 2010-2019

Source: own study

Table 3. Share of irregular, cyclical and seasonal changes in the overall volatility of rye prices by time horizon

Month	Changes [%]		
	non-regular	cyclical	seasonal
1	39.7	27.8	32.5
2	27.8	45.9	26.3
3	13.7	59.2	27.1
4	7.9	66.4	25.7
5	4.9	71.7	23.4
6	3.7	77.0	19.3
7	3.3	81.1	15.6
9	2.5	90.2	7.3
11	2.4	95.8	1.8
12	3.0	97.0	0.0
Average	10.9	71.2	17.9

Source: own calculations

Cyclical fluctuations were characterized by a variable amplitude: in the years 2010-2013, the difference between the lower and upper turning point of the cycle was about PLN 180, whereas in the period 2014-2018 this amplitude decreased to PLN 80. MCQ value = 2.94 indicates that after 3 months of unidirectional changes a new cycle started. Irregular fluctuations usually did not exceed 5% and the maximum amplitude of this type of fluctuation was 10%.

The share of irregular, cyclical and seasonal changes in the overall variability of rye prices depending on the time horizon of changes is presented in Table 3. Within the time horizon of 1 month, irregular changes dominated, which constituted 39.7% of overall variability, while seasonal changes constituted 32.5% and cyclical changes 27.8%. In the longer horizon, cyclical

changes dominated, which in the two-month horizon constituted 46% and in the three-month horizon almost 60% of variability. Cyclical changes in the year were 71.2% on average, seasonal – 17.9% and irregular – 10.9% of the overall price variation of rye.

## DISCUSSION

The variability of prices of agricultural products is of significant importance in price risk management, which has been reflected in relatively numerous scientific articles on this subject [Figiel at al. 2012, Hamulczuk 2009, 2014, Olszańska 2011]. Among others, Bolesław Borkowski and Monika Krawiec [2010] drew attention to the need to learn about mechanisms describing the behavior of cereal prices and their variability. Michał Jerzak [2009] examined the volatility of prices on the corn market in the years 1996-2008, pointing out that until 2006 price fluctuations were small, and there were downward tendencies on the market. The author states that the strongest price increase took place in 2007, when the price of wheat increased by 58% (compared to the previous year), rye by 56%, barley by 59% and maize by 47%. The rye price volatility index ranged from 5.9% in 2005 to 26.4% in 2008, while, in this study, covering the period 2010-2018, the rye price variation index ranged from 4.0 to 27.2%.

A characteristic feature of the corn market is the seasonality of supply and related seasonal price fluctuations. A gradual increase in prices in subsequent months after harvest is mainly related to the costs of storing [Figiel 2002]. Statistical analyses carried out in this paper confirm that, in the years 2010-2018, seasonal fluctuations in rye prices were statistically highly significant, with the highest prices in June (105%) and the lowest in August (91%). Michał Jerzak and Magdalena Śmiglak [2006], analyzing seasonality indices of rye prices in the years 1990-2006, showed that the seasonal peak in prices occurred in May (106.9%), while the lowest prices occurred in August (90.1%). The share of seasonal fluctuations in the overall volatility of rye prices was 17.9%, on average, per year. A much greater effect of seasonal fluctuations (31% annual average) on the overall price volatility (in the same period) was observed in the case of maize, where the highest prices were in August (107.1%) [Utnik-Banaś 2019].

## CONCLUSIONS

1. The production of rye is steadily falling both in the world and Poland. Between 1961 and 2017, the volume of rye production in Poland decreased more than three times, while production per hectare almost doubled.
2. The price of rye in the last nine years more than doubled from PLN 327 per ton in January 2010 to PLN 719 per ton in December 2018. The annual price variation coefficient ranged from 4% to 27.2%.
3. Seasonal fluctuations in rye prices were statistically highly significant. In 2010-2012 the highest prices were in February-May, while, in the following years, the seasonality pattern changed: the highest prices were in June (105%) and the lowest in August (91%) with an average amplitude of seasonal fluctuations of 14%.



4. The share of irregular, cyclical and seasonal changes in the overall variability of rye prices depended on the time horizon of changes. Irregular changes dominated within the 1 month horizon and accounted for 39.7% of overall variability, while seasonal changes accounted for 32.5% and cyclical changes for 27.8%. Cyclical changes in the year were 71.2%, on average, seasonal – 17.9% and irregular – 10.9% of overall variability of rye prices.

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## ZMIENNOŚĆ CEN ŻYTA W POLSCE W LATACH 2010-2018

Słowa kluczowe: zmienność cen, wahania sezonowe, dekompozycja szeregów czasowych

### ABSTRAKT

Celem artykułu jest próba określenia zakresu zmienności cen żyta. Przeprowadzono także dekompozycję szeregu czasowego cen, wyróżniając wahania sezonowe, cykliczne i nieregularne. Rynek żyta, to rynek produktu wytwarzanego sezonowo, ale o okresie przechowywania dłuższym niż jeden sezon, co wpływa na okresowe zmiany cen, na które nakładają się zmiany koniunkturalne. Przedmiotem badań były ceny żyta w odstopniowaniu miesięcznym za lata 2010-2018 ze Zintegrowanego Systemu Rolniczej Informacji. W analizowanym okresie cena nominalna żyta wzrosła ponaddwukrotnie – z poziomu 327 zł za tonę w styczniu 2010 roku do 719 zł za tonę w grudniu 2018 roku. Współczynnik zmienności cen żyta wynosił od 4,0 do 27,2%. Dekompozycja szeregu czasowego cen wskazuje na występowanie zarówno wahań sezonowych, jak i cyklicznych oraz nieregularnych. Amplituda wahań sezonowych wynosiła średnio 14%, najwyższe ceny były w czerwcu (105%), a najniższe w sierpniu (91%). W skali roku zmiany cykliczne stanowiły średnio 71,2%, sezonowe – 17,9%, a nieregularne – 10,9% ogólnej zmienności cen żyta. Produkcja żyta systematycznie spada zarówno na świecie, jak i w Polsce.

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