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IMPACT OF CHANGES IN AGRICULTURAL COMMODITY PRICES ON CHANGES IN RETAIL PRICES OF AGRI-FOOD PRODUCTS IN POLAND IN 2007–2016

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Abstract. This paper presents the impact of changes in prices of agricultural products on changes in retail prices of agri-food products. The basis for the study was data on changes in prices of milk, wheat, pork and poultry and derived products in Poland in 2007–2016. A relationship was discovered between the variables, on one side, and lags between the examined time series, on the other. The cross-spectral analysis was used to study the periodicity of changes and lags between time series.

Keywords: food industry, agriculture, retail, prices

INTRODUCTION

In the classic approach, the efficiency of agricultural raw materials production is conditional on access to basic productive inputs: land, labor, and capital. As a consequence, this approach enables the determination of attainable production volumes (Zieliński, 2002). This, in turn, is a success factor in running agricultural activities and an incentive for producers to modernize and restructure their agricultural holdings. The expected result of the transformation is a higher quality product sold at a better price which in turn improves the profitability of the whole enterprise. The effectiveness of this path of agricultural development is evidenced by the outcomes of Western European agricultural companies: the introduction of futures and options, vertical integration (forward transactions) or participation of agricultural producers in distribution channels (establishment of cooperatives) (Chotkowski and Deluga, 2003).

On the other hand, the efficiency of agri-food enterprises is a reflection of the supply side (Firlej, 2008). The ratio of retail food prices to raw material prices indicates the share of agricultural production in food consumption (Poczta and Kiryluk, 2004) and is a success factor for the agri-food industry. In food processing, raw material costs can significantly affect the operating costs and prices of products offered by companies in the sector.

The price formation process attracts particular interest in periods of rapid transformation. Quick changes in raw material prices, which affect product prices, are usually observed in energy markets (one notable example is the fuel crisis in the 1970s). However, the energy markets are characterized by strong shifts in prices of raw materials (especially crude oil, natural gas and steam coal) (Grudziński, 2009) even in periods of prosperity (Pawlak, 2014). As emphasized by the World Bank, the research on the structure of food prices is a global problem resulting from the economic transformation around the world (World Bank, 2009). Among the key factors affecting significant changes on the grocery market, the World Bank cites the following:

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1. The rate of population growth, which is expected to decrease in the coming years;

2. The growth rate of per capita income, which may also decline;

3. Changes in the impact of scientific and technological progress.

The above factors affect the global prices of basic products, including foodstuffs. The analysis of the price structure is an issue of relevance in the context of Poland's food security and of the development of agriculture and agri-food sectors in Poland.

PURPOSE AND METHODOLOGY OF RESEARCH

The purpose of this paper was to study the impact of changes in buying-in prices of agricultural products on changes of retail prices of agricultural products in Poland in 2007–2016. Elements of the cross-spectral analysis, i.e. changes in the spectral density values of individual variables, the coherence square, and phase spectrum values were used in the analysis of causality between variables. This method examines the time series to trace cyclic changes occurring with a given frequency; such changes reflect the emergence of cycles with different periods, amplitudes and contributions to the overall evolution of the time series (Łuczyński, 2015). A relatively high value of the first two indicators proves the significance of a given frequency in the formation of a series (spectral density) and the strength of dependence between series (square of coherence). Changes in phase spectrum values were used to determine the shifts in the relations between two variables (precedence/succession of a time series over the other) for selected relevant frequencies. An additional tool used in the study was the price index which enabled a comparative analysis of the evolution of variables over time.

This study relied on data collected in the retail product price monitoring project run in Poland[1]. The research uses monthly data for the 2007–2016 period. The "Purchase and prices of agricultural products" dataset was retrieved from the Central Statistical Office to access data on prices in the agricultural production sector recorded in the same period. Changes in the following prices were selected from the available data (current prices in PLN): buying-in price of wheat (unit: 100 kg); cow's milk (unit: 1 hl); poultry (unit: 1kg); pigs (hereinafter: buying-in price of pork, unit: 1 kg); Łowicz milk 3.2% (hereinafter: retail price of milk, unit: 1 l); whole chicken (hereinafter: buying-in price of chicken, unit: 1 kg); cheese (unit: 1 kg); butter block (hereinafter: butter, unit: 200 g); "Piątnica" 18% fat cream (hereinafter: cream, unit: 200 g); bread (unit: 1 kg); Kaiser rolls (unit: 50 g); Poznań flour, type 500 (hereinafter: flour, unit: 1 kg); pork loin bones (hereinafter: pork loin, unit: 1 kg); Podwawelska sausage (hereinafter: sausage, unit: 1 kg).

For reasons of data availability, each of the series contains 84 observations. Furthermore, each of the price change series was checked for stationarity on a month-by-month basis using the Dickey–Fuller and Philips–Perron tests (Mahadeva and Robinson, 2004).

For the Dickey–Fuller test, the null hypothesis is that the time series is non-stationary due to the presence of a unit root. Conversely, the alternative hypothesis assumes that the series is stationary. The test uses a modified version of the ADF test formulated as:

$$\Delta y_t = \delta y_{t-1} + \Sigma_{j=1}^{k} \alpha_j \Delta y_{t-j} + \varepsilon_t,$$

where y_t designates the observed variable series, and k is the number of lagged differences of the variable.

The DF statistics, calculated using the Student's t-value, is above the critical level, and thus there is no reason to reject the null hypothesis of non-stationarity of the time series under consideration. The relevant critical values were specified by MacKinnon (1991).

The Philips-Perron unit root test is robust to autocorrelation and heteroscedasticity of unknown form. The test hypothesis assumes the time series is non-stationary.

According to test results, all time series covered by this study were found to be stationary[2].

[1] A cooperative project of dlahandlu.pl and portalspożywczy.pl websites. As part of the "Shopping Cart" project, product prices are monitored in several categories of stores in the largest Polish cities (delicatessen, discount stores, supermarkets, hypermarkets, neighborhood stores; a total over 20 different retail chains). For each month, the average monthly price of a given product is established based on a research sample of 50 to 120 units (dlahandlu.pl, n.d.).

[2] More about the test can be found in Phillips and Perron, 1988.

SCRUTINY OF CHANGES IN RAW MATERIALS AND AGRI-FOOD PRICES IN 2007–2016

Prices of agricultural products have a potential impact on changes in retail prices of agri-food products. In order to capture the relevant trends and to conduct the analysis, selected results were presented for the time series of monthly price changes of selected products.

As shown in Figure 1, the most important frequency of changes in buying-in prices of milk is 0.02, followed by 0.09, which corresponds to changes in a two- and seven-month period. In the case of changes in retail prices, a stronger significance of long-term trends was observed; this may result from the very nature of this analysis which strengthens the importance of long-term movements. Considering the coherence square chart for the tested relation, it can be concluded that the index reaches a high level at a frequency of 0.02, which in this case corresponds to two-month cycles. The spectral value for this frequency indicates that the change in milk prices occurs ca. 1.3 months before the change in retail prices of milk.

Similarly, in the case of spectral density (Fig. 2) of butter prices, long-term movements are highly significant. However, in this relationship, two frequencies are relevant for this analysis: 0.01 and 0.09, which correspond to movements within one- and seven-month cycles. In the case of the first frequency, the spectrum value indicates that changes in milk price precede the

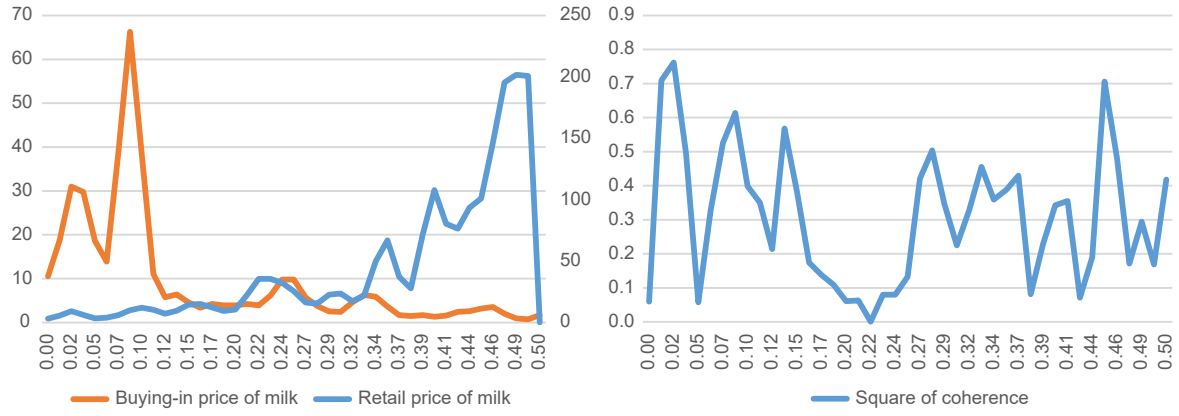

Fig. 1. Spectral density and square of coherence for changes in buying-in and retail prices of milk
Source: own elaboration based on data from dlahandlu.pl (n.d.) and GUS (n.d.).

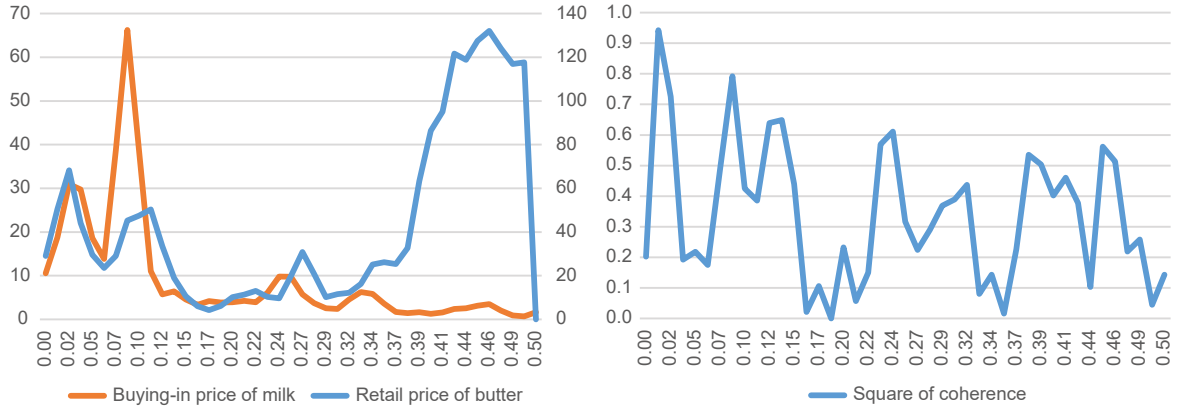

Fig. 2. Spectral density and square of coherence for changes in buying-in prices of milk and retail prices of butter
Source: own elaboration based on data from dlahandlu.pl (n.d.) and GUS (n.d.).

changes in butter prices by at least 0.3 months. In the case of the other (longer) cycle, the corresponding delay is 1.6 months.

The relationship between changes in buying-in prices of milk and changes in cream prices (Fig. 3) reaches the highest significance in the case of cycles with a frequency of 0.02, i.e. two-month periods. As in previous cases, this is yet another milk product (in this case, cream) which indicates the importance of long-term changes. Changes in milk prices occur only 0.2 months before the changes in cream prices.

The last dairy product covered by this analysis is cheese. In this case, the density of spectral price changes grows along with the increase in frequency (as shown in Fig. 4). Two important frequencies (0.01 and 0.09) can be indicated in the test relationship, which correspond to cyclic movements of one month and seven months, respectively. In the first case, changes in milk prices precede changes in cheese prices by half a month. In the case of seven-month cycles, the advance is 0.09 months.

As shown by the results of this analysis, over the study period, changes in buying-in prices of milk had a slight impact on prices of dairy products. In all time series, this relationship was marked by a lag between the occurrence of changes. The weakness of the relationship resulted from the low susceptibility of dairy products

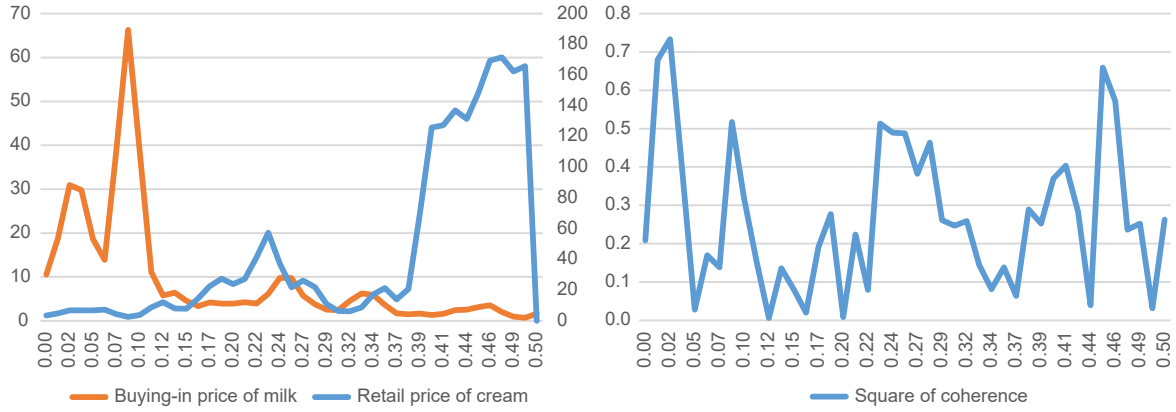

Fig. 3. Spectral density and square of coherence for changes in buying-in prices of milk and retail prices of cream
Source: own elaboration based on data from dlahandlu.pl (n.d.) and GUS (n.d.).

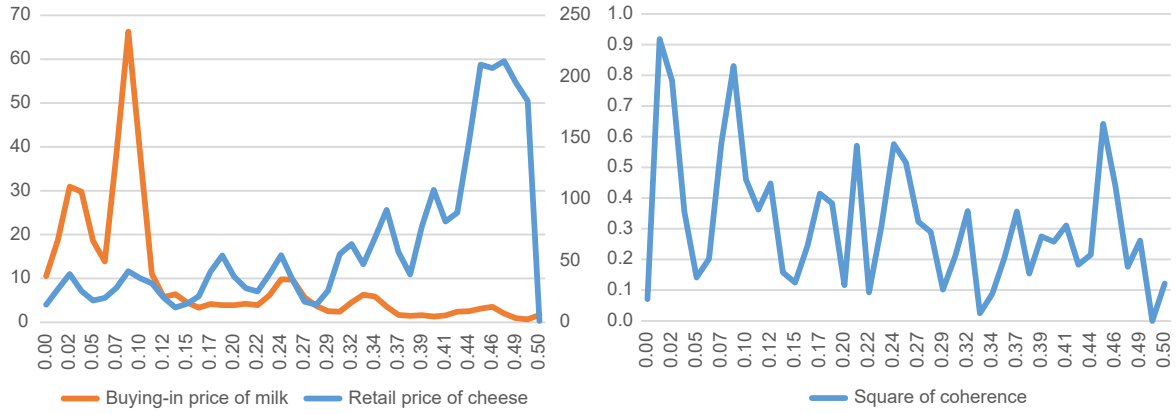

Fig. 4. Spectral density and square of coherence for changes in buying-in milk prices and cheese prices
Source: own elaboration based on data from dlahandlu.pl (n.d.) and GUS (n.d.).

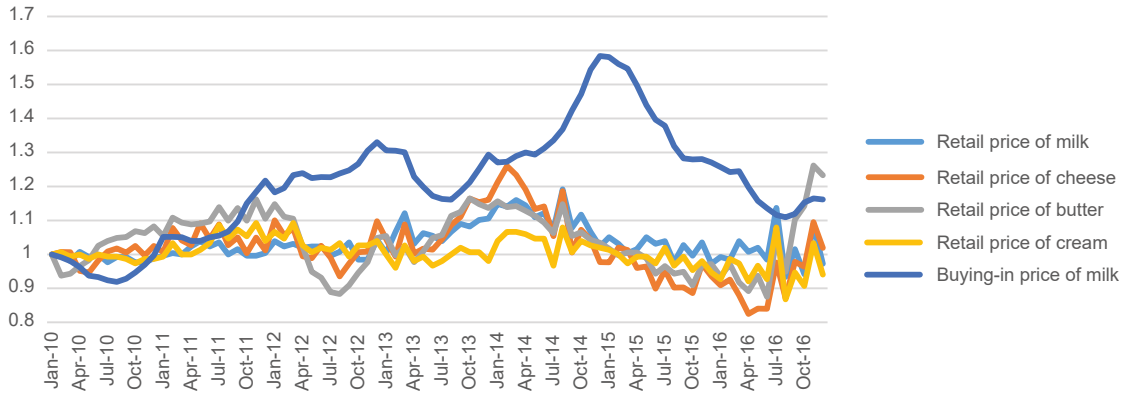

Fig. 5. Indexes for buying-in and retail prices of milk and butter, and for cheese and cream prices in 2007–2016
Source: own elaboration based on data from dlahandlu.pl (n.d.) and GUS (n.d.).

to short-term fluctuations, which in turn determined the changes in milk prices in the primary market. As shown in Figure 5, there was a clear increase in the margin earned by agricultural producers, resulting from the lower volatility of processed product prices and a significant increase in milk prices per hectoliter.

In the case of spectral density values for changes in wheat prices (Fig. 6), a significant impact of short-term fluctuations (0.05 and 0.17) can be observed. In turn, fluctuations in flour prices were significantly affected by long-term fluctuations. The relationship between these products suggests the existence of long-term relationships corresponding to fluctuations at a frequency of 0.38 (i.e. 29-month cycles, nearly two and a half years). At this frequency, changes in wheat prices were observed to occur almost two months in advance.

As in the case of flour, spectral density of changes in bread prices rises with increasing frequency, thus highlighting the significance of long-term fluctuations (Fig. 7). However, this relationship is clearly characterized by a strong short-term dependence when it comes to one-, two- and four-month fluctuations. For each of them, lagged changes in bread price were observed to take place 0.2 months following the changes in wheat prices (on a monthly and quarterly basis).

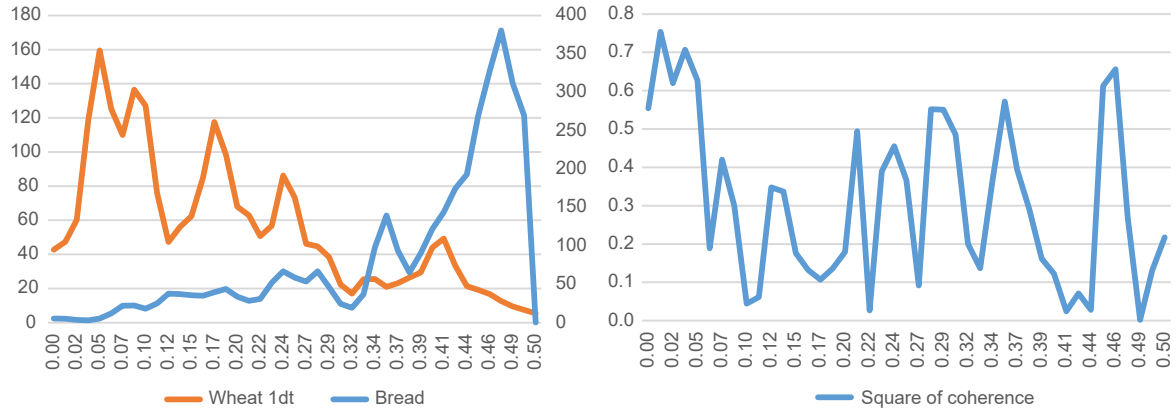

Fig. 6. Spectral density and square of coherence for changes in buying-in prices of wheat and changes in flour prices
Source: own elaboration based on data from dlahandlu.pl (n.d.) and GUS (n.d.).

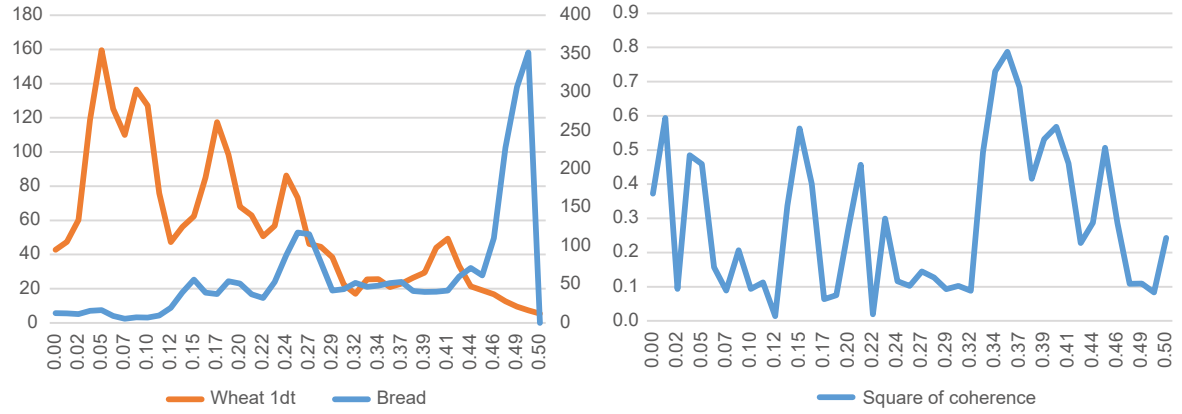

Fig. 7. Spectral density and square of coherence for changes in buying-in prices of wheat and changes in bread prices
Source: own elaboration based on data from dlahandlu.pl (n.d.) and GUS (n.d.).

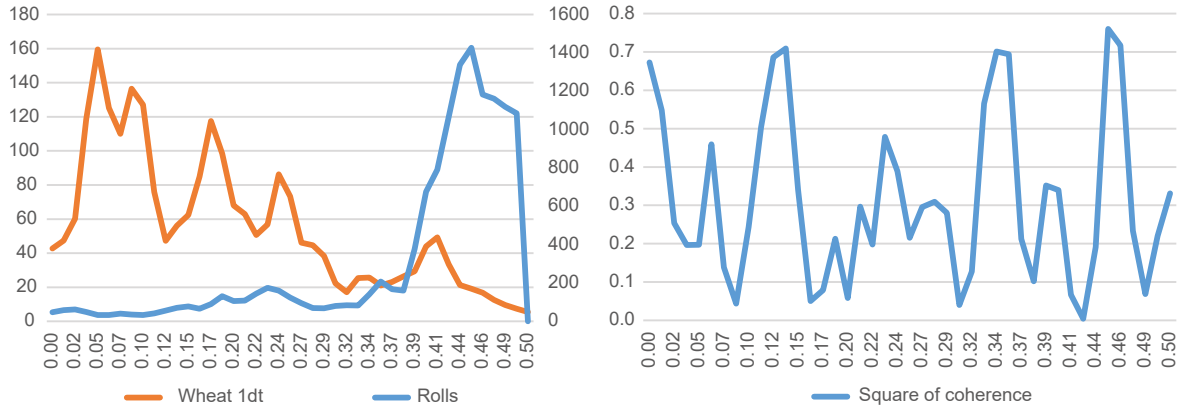

Fig. 8. Spectral density and square of coherence for changes in buying-in prices of wheat and changes in prices of rolls
Source: own elaboration based on data from dlahandlu.pl (n.d.) and GUS (n.d.).

As shown by the analysis of dependence between changes in prices of rolls and changes in buying-in prices of wheat (Fig. 8), there are at least two significant relationships corresponding to the frequency of 0.13 (a coherence square of 0.71) and 0.34 (a coherence square of 0.7), respectively. In the case of shorter (11-month) fluctuations, changes in wheat prices were observed to occur about half a year before the changes in retail prices of rolls, whereas in the case of longer (28-month) fluctuations, the lag was two months.

As shown by the analysis of changes in prices of wheat products, dependencies exist between changes in wheat prices and changes in prices of these products. However, the impact is relatively small in relation to the general price level. In the case of most significant relationships, changes in wheat prices occur ahead of changes in prices of derivative products. An exception were the fluctuations in annual prices of rolls, which took place ahead of changes in wheat prices. The increase in prices of bread rolls enables wheat prices to increase to a point where consumer demand starts to decline, which leads to a reduction in the price of bread rolls. A decrease in demand for wheat implies larger quantities of wheat being available on the market and results in a drop in wheat prices. Note however that this anticipation is true for frequencies with a very low

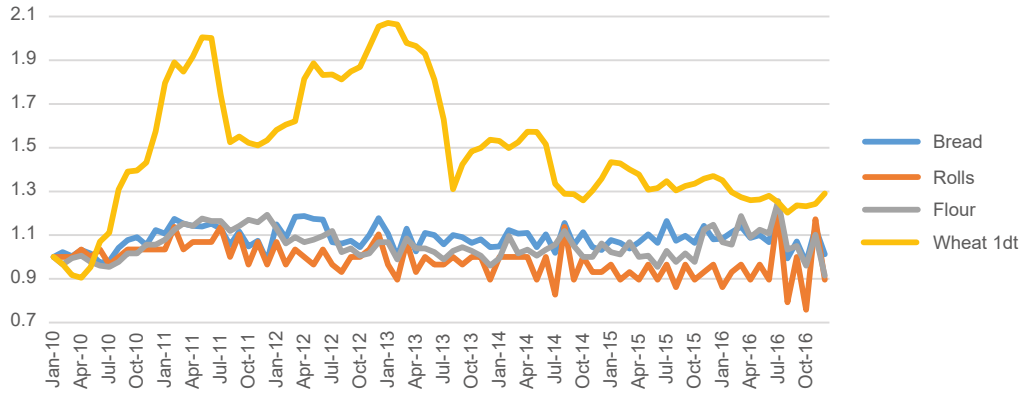

Fig. 9. Index of prices of wheat, wheat flour, bread and rolls in 2007–2016
Source: own elaboration based on data from dlahandlu.pl (n.d.) and GUS (n.d.).

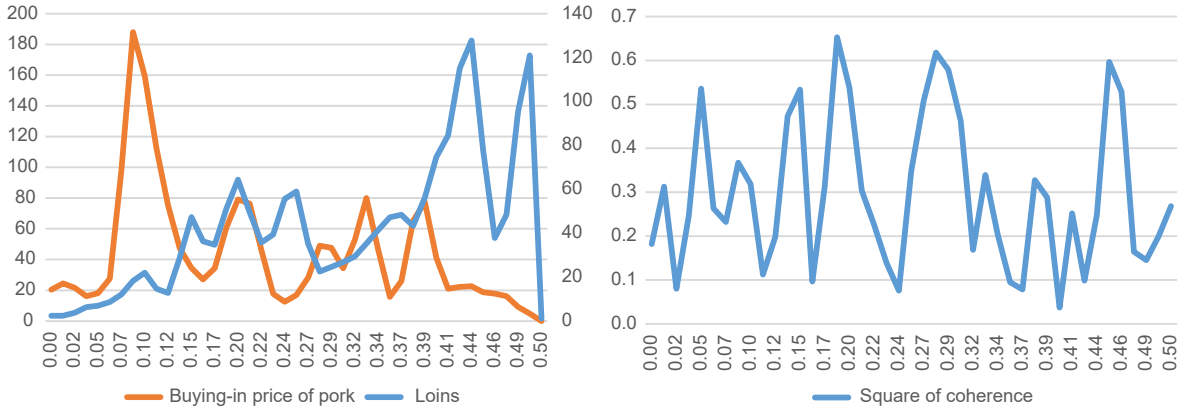

Fig. 10. Spectral density and square of coherence for changes in buying-in prices of pork and changes in retail pork loin prices
Source: own elaboration based on data from dlahandlu.pl (n.d.) and GUS (n.d.).

spectral density of both variables, and thus with a minor contribution to the overall pace of relevant price changes. In the study period, as in the case of changes in milk prices, an increase in profitability was recorded by agricultural raw material producers (Fig. 9). The reason for the above was an increase in wheat prices with a simultaneous decline in growth rates of prices of derived products.

Figure 10 illustrates the relationship between changes in pork prices and changes in pork loin prices. The coherence square does not suggest a strong unambiguous relationship (expressed with a score above 75). The strongest relationship was recorded at the frequency of 0.18 (with a coherence square of 0.65), i.e. for 15-month-long fluctuations. Changes in pork loin prices occur one and a half months after the changes in pork prices.

As shown in Figure 11, the spectral density of sausage price changes rises along with increasing frequency. As regards the relationship between changes in sausage prices and changes in the procurement price of pork, the significance for the equal frequency can be indicated 0.09 and corresponding to seven-month fluctuations. For this frequency, the spectral density of pork price changes reaches a high level of 188. In this fluctuation period,

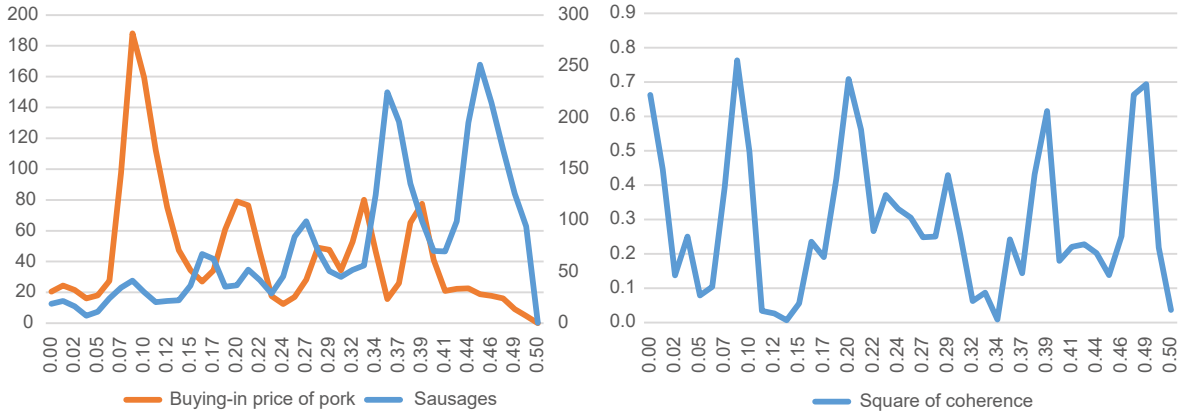

Fig. 11. Spectral density and square of coherence for changes in buying-in prices of pork and changes in retail sausage prices
Source: own elaboration based on data from dlahandlu.pl (n.d.) and GUS (n.d.).

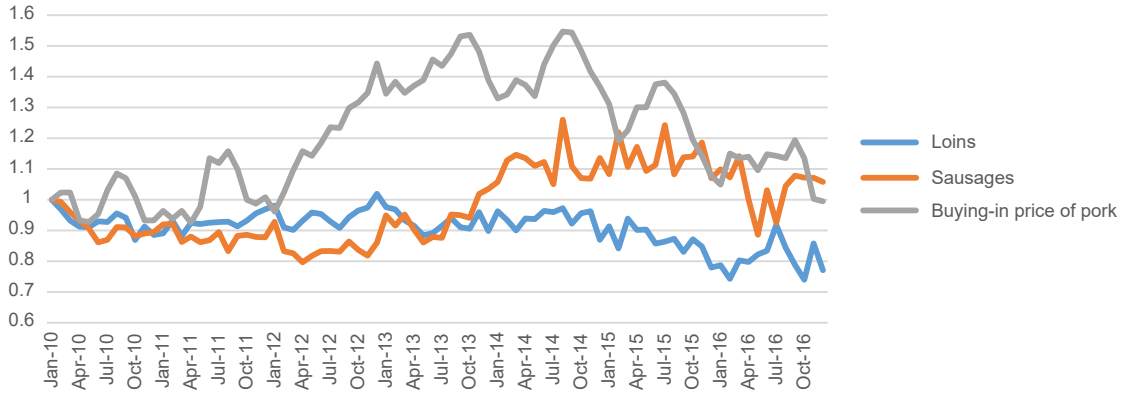

Fig. 12. Indexes for buying-in of prices of pork, sausage prices, and loin prices in 2007–2016
Source: own elaboration based on data from dlahandlu.pl (n.d.) and GUS (n.d.).

changes in sausage prices occur about one month before the changes in pork prices. This suggests that retail sausage prices have a significant impact on buying-in prices obtained by farmers.

As shown by the analysis of changes in the value of ranks relating to the prices of pork and pork products, no strong objective relationships exist between cyclical changes in retail prices of pork loin and changes in buying-in prices of pork. However, a significant relationship was found to exist between the buying-in prices of pork and retail prices of sausages, such that the retail product price affects the buying-in price. Figure 12 illustrates the price changes in the study period, showing that while there was a real increase in retail prices of sausage and in buying-in prices of pork, the price of pork loin remained at a similar level.

Figure 13 evidences a strong relationship between the variables during the period considered. Two frequencies can be indicated (0.09 and 0.15) for which the coherence square suggests a significant relationship. They correspond, respectively, to 7-month and one-year fluctuation periods. In the case of shorter fluctuations, changes in buying-in prices of chicken occur about two months in advance of changes in retail prices of chicken.

Fig. 13. Spectral density and square of coherence for changes in buying-in prices of chicken and changes in retail prices of chicken
Source: own elaboration based on data from dlahandlu.pl (n.d.) and GUS (n.d.).

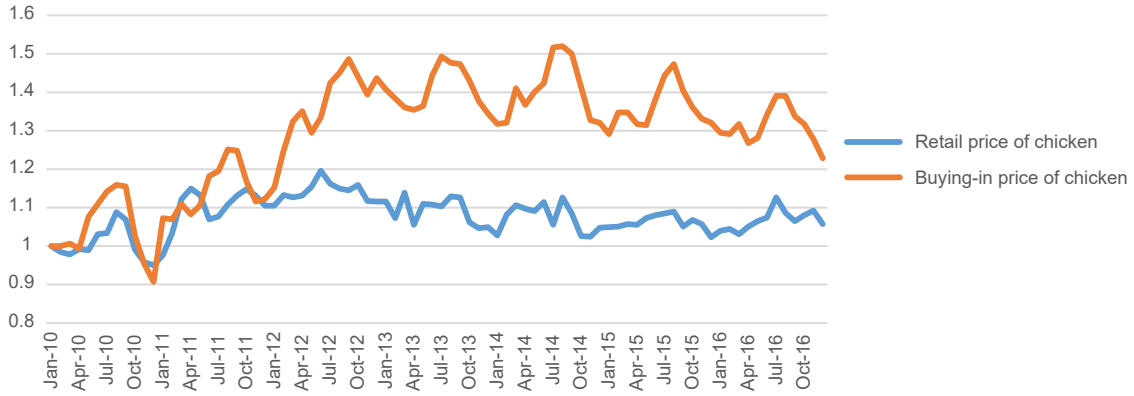

Fig. 14. Index of buying-in prices of chicken and retail prices of chicken in 2007–2016
Source: own elaboration based on data from dlahandlu.pl (n.d.) and GUS (n.d.).

It is the opposite for longer fluctuation periods where changes in the buying-in price take place about three months before changes in the retail market.

As shown by the analysis of the time series of changes in prices of poultry and poultry products, changes in buying-in and retail prices of chicken have a reciprocal impact, i.e. changes in retail prices affect the changes in buying-in prices while changes in buying-in prices affect the changes in retail trade. Figure 14 further indicates that the study period witnessed an increase in profitability of agricultural producers by maintaining retail prices at a similar level while increasing purchase prices.

CONCLUSION

Changes in prices of agricultural products may be determined by many factors. In the case of beef products, prices depend on the price level recorded in the European Union and on the euro exchange rate. This is because a large part of beef production is exported from Poland to other EU countries (Zawadzka and Pasińska, 2016). A similar relationship can be observed in the oilseeds market where prices are found to be dependent on price changes at the MATIF exchange in Paris (Jerzak and Łąkowski, 2013; Rosiak, 2014). The globalization

of agri-food processing also has an impact on product prices, as indicated by Bełdycka-Bórawska et al. (2015). According to J. Zaród's approach, the key determinants of changes in prices of agricultural products include structural factors (e.g. yield, sown area, consumption, import, export) and cyclical factors (e.g. extreme weather events, exchange rates) (Zaród, 2017).

The results presented in this paper demonstrate the existence of actual relationships between agricultural production prices and retail prices of agri-food products in the study period. Below are the key conclusions from this research:

1. In the case of dairy products and wheat-based products, changes in buying-in prices were observed to precede changes in retail trade. It was pointed out that, as regards these products, agricultural producers improved their situation over the study period because buying-in prices went up while retail prices remained at a similar level;

2. Changes in pork prices result from changes in the retail market and have an impact on buying-in prices;

3. Changes in retail and buying-in prices of poultry influence each other;

4. In the case of times series of changes in buying-in prices, there is a significant impact of short-term fluctuations on the overall evolution of the series;

5. Long-term fluctuations played a greater role in shaping the pace of retail price changes.

To sum up, changes in prices of agri-food products are not primarily determined by prices of agricultural products. Instead, they are also impacted by other factors such as changes in the production process, profit margins on the final product and changes in the global market for the product considered. Thus, the results of this study can be used to provide a more accurate specification of determinants of final retail prices by taking into consideration additional macroeconomic variables.

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