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**DETERMINANTS OF PURCHASE PRICES OF APPLES
FOR PROCESSING IN POLAND**

Key words: fruits for processing, apples for processing, apple production, purchase prices, fruit processing, export prices, concentrated apple juice

ABSTRACT. The aim of the study was to identify the significant determinants of the level of purchase prices of apples for processing in Poland. The subject of the research is purchase prices of apples for processing published in the semi-annual Fruit and Vegetable Market by the Institute of Agricultural and Food Economics – National Research Institute. The study showed that the purchase prices of apples for processing in Poland were significantly influenced by the export prices of apples, the volume of the export of concentrated apple juice, and the export prices of concentrated apple juice. The increase in the export prices of apples may be caused by the growing demand for Polish apples on foreign markets, which may result in lower availability of apples for processing. Therefore, the increase in the export prices of apples was accompanied by the increase in the purchase prices of these fruits for processing. The volume of export of concentrated apple juice depends on the volume of production of this processed product, which is influenced by the volume of apples harvested in Poland. The volume of apples harvested is negatively correlated with the purchase prices of apples for processing. Therefore, the increase in the export of concentrated apple juice was accompanied by relatively low purchase prices of apples for processing. The level of export prices of concentrated apple juice was strongly related to the level of purchase prices of apples for processing and the increase of purchase prices of apples was accompanied by an increase in export prices of concentrated apple juice.

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INTRODUCTION

Apples are grown on all continents, in 95 countries around the world. Poland is one of the world's largest apple producers. According to FAOSTAT data [2023], between 2018 and 2021 the average apple production volume in Poland was 3.7 million tonnes. It was the fourth largest production volume after China (42 million tons), the United States (4.7 million tons), and Türkiye (4 million tons).

Consumers are aware of the nutritional properties of apples and appreciate them. These fruits contain among others fibre, minerals, vitamins and polyphenols, which have antioxidative and anticancer properties [Kalinowska et al. 2014, Skinner et al. 2018]. Apples are some of the most frequently consumed fruits and the global consumption of apples and apple products per capita was increasing [Fedrigotti, Fischer 2020]. Apples are not only consumed fresh but they are also processed into juices (mainly concentrated ones), mousses, pulp, compotes, dried fruit, jams and marmalades, wines and ciders, and vinegar [Walkowiak-Tomczak 2017].

Apple production in Poland has been developing for many years. According to Augustyn Mika [1995], before World War II fruit in Poland was grown almost exclusively in orchards belonging to peasants as well as those located near manors and other houses. After the war, for 40 years Poland mainly followed the fruit production model developed in the US. American and Canadian apple cultivars (e.g. McIntosh, Spartan, Cortland, Idared) were grown on vigorous rootstocks. In the early 1990s, the modernisation of Polish fruit farming began. Orchards with dwarf trees were established and other apple cultivars were grown (Jonagold, Champion, Golden Delicious, Gala).

Currently, apple orchards in Poland occupy an area of 150,000 ha. The annual production volume is over 4 million tonnes [GUS 2023]. According to the EUROSTAT data [2023], 38% of the annual yield of apples is processed however, according to the balance made out by Bożena Nosecka et al. [2023], about 50-70% of apples is processed in Poland. For apple growers who direct most of their harvest to processing, the income from the sale of apples for processing has a considerable share in the total income from orchard production. Therefore, the purchase prices of apples paid by fruit processing plants and collection points (intermediaries) significantly influence the gross and net income of apple producers in Poland. When they were too low, apple producers in Poland often started protests [Portalspożywczy.pl 2018a] and accused fruit processing plants of price fixing [LIR 2019]. In consequence, the government intervened [Portalspożywczy.pl 2018b].

In 2021 the Competition and Consumer Protection Office [UOKiK 2022] inspected apple collection points and processing plants and found that the purchase price of apples for processing in Poland is set by processing plants. The price of apples for processing supplied by fruit producers to collection points is determined by the price at which collection points sell the fruit to the processing plant. The price paid to the producer depends on the volume

of delivery, the relationship between the buyer and the supplier, the quality of the fruit and the distance from the collection points if apples are collected from producers by the buyer. In addition, the collection point charges producers a variable margin for its services (about 10% or 0.02-0.05 PLN per 1 kg of apples). According to the processing plants inspected by the Competition and Consumer Protection Office in 2021, their apple purchase prices depended on the current demand and supply of these fruits and processed products. The mentioned factors were: the supply of apples in the entire season (the yield of apples in Poland and in the world) and in a particular purchasing period, the quality of apples in a particular season, the possibilities and conditions of selling processed apple products, e.g. the prices of concentrated apple juice on the global market [UOKiK 2022].

The problem of the determinants of the prices of agricultural crops has been researched and presented in scientific publications. According to Mariusz Hamulczuk et al. [2012], the main factors affecting the prices in the agri-food sector are: the demand and supply, the biotechnical nature of agricultural production, indirect connections between the market and the consumer, intermarket connections, connections with prices on the global market as well as the influence of agricultural and trade policies. William Tomek and Kenneth Robinson [2001] indicated the availability of the raw material as a significant determinant of the purchase prices of fruit for processing. The availability of fruit is influenced by the seasonality of fruit production, the market structure, as well as competition between fruit recipients and suppliers, i.e. fruit producers. Sylwia Kierczyńska [2019] found a significant correlation between the yield of apples in Poland and the purchase prices of apples for processing. Moreover, Sylwia Kierczyńska [2015] also observed a positive correlation between the export prices of concentrated apple juice and the purchase prices of apples for processing and a negative correlation between the purchase prices of apples for processing and the volume of production and export of concentrated apple juice.

Poland is one of the world's largest producers and exporters of apples [Nosecka 2014]. The largest producers and exporters of apples are also leading producers and exporters of concentrated apple juice [Bugala 2014]. According to Bożena Nosecka [2017], between 2010 and 2012 Poland's export orientation index for concentrated apple juice amounted to 117% in terms of quantity and 96% in terms of value. Between 2013 and 2015 the index amounted to 84% and 88%, respectively. Paweł Kraciński [2018, 2023] observed that China had a dominant position on the international concentrated apple juice market. However, between 2007 and 2022 the volume of concentrated apple juice exported from China and the share of this country in the global export of concentrated apple juice decreased. Poland is the second largest global exporter of concentrated apple juice. Both the export volume and Poland's share in the global exports of concentrated apple juice increased. A similar trend was observed for Türkiye, Moldova, and the US [Kraciński, Wicki 2020].

Domestic fruits are mainly used for the production of concentrated apple juice in Poland, whereas imported apples only supplement the domestic production [Zaremba

2014]. Moreover, concentrated apple juice is also imported to Poland from the countries with relatively low export prices [Nosecka 2017]. It is used for the production of juices, drinks, and nectars for the domestic market, or it is re-exported after mixing with juice produced by domestic processing plants. By mixing domestic juices with cheaper imported juices exporters can offer their products at lower prices [Nosecka et al. 2012].

As results from the research and analyses provided in the reference publications, the purchase prices of apples for processing may be determined by many factors, which on the supply side include: volume of apples harvested in Poland and in countries competing with Poland on the market of concentrated apple juice, the availability of raw material for processing from domestic harvest and import, as well as the volume of concentrated apple juice production in Poland and import of concentrated apple juice to Poland. On the demand side, there are factors such as the demand for dessert apples and the demand for concentrated apple juice on the international market. The relation between the demand and supply is reflected in the prices of dessert apples and prices of concentrated apple juice. The aim of this study was to identify the significant determinants of the purchase prices of apples for processing in Poland. The scope of the research covers the years (seasons) from 2004/2005 to 2021/2022.

RESEARCH MATERIAL AND METHODOLOGY

The purchase prices of apples for processing published in the semi-annual “Fruit and Vegetable Market” by the Institute of Agricultural and Food Economics – National Research Institute [IERiGŻ-PIB 2005-2023] were used as the research material. The average annual prices of apples for processing in harvesting seasons, ex-processing plants, are published. The data on the yield of apples harvested in individual countries came from the FAOSTAT database. The data on the production of concentrated apple juice, the exports of apples and concentrated apple juice from Poland in individual seasons, and the prices of apples and concentrated apple juice were found in the semi-annual Fruit and Vegetable Market.

The significance of the relationship between the purchase prices of apples for processing and their potential determinants was verified with the Pearson correlation coefficient. The relationship between the purchase prices of apples for processing (the dependent variable) and selected explanatory variables which were significantly correlated with these prices were analysed with the multiple regression method – a single-equation econometric model was established as a function of many factors. The estimators of the structural parameters of the model were estimated with the least squares method and analysed with backward stepwise regression. The Statistica PL 13.3 package (Statsoft) was used for statistical analysis.

The resulting econometric model was verified formally and statistically. The fit of the model to the empirical data was assessed on the basis of the values of the coefficient of determination (R^2), the coefficient of variation (ve), the standard error of the estimate (se), and the mean absolute percentage error ($MAPE$). Student's t test was used to assess the significance of the structural parameters of the model. The significance of the entire model was assessed with the Fisher-Snedecor test. The multicollinearity between the explanatory variables was verified with the variance inflation factor (VIF). The random component was checked for symmetry and normality of distribution with the Shapiro-Wilk test, for homogeneity of variance – with the Goldfeld-Quandt test, for autocorrelation – with the Durbin-Watson test, and for randomness of residuals – with the series test [Stanisz 2007, Stańko 2013].

RESULTS

PURCHASE PRICES OF APPLES FOR PROCESSING IN POLAND

Apples as a raw material for processing are sold all year round in Poland. In the summer months, apples harvested after thinning are delivered to processing plants. Although these fruits are not ripe yet, they are a valuable raw material for processing due to their high acidity. Apart from that, in the autumn months ripe fruit growing on trees are harvested and those which have fallen from trees are collected for further processing. In winter and spring, stored fruits, including those categorised as waste after the sorting of dessert fruits, are sold to processing plants. Although apples for processing are sold all year round, in the autumn months, immediately after the harvest, their supply is the highest.

The average annual purchase prices of apples reflect the average level of purchase prices in the seasons, i.e. from July to June of the next year. During the period analysed in our study, i.e. between the seasons of 2004/2005 and 2021/2022, the purchase prices of apples ranged from 0.15 PLN per kg in 2008/2009 to 0.95 PLN per kg in 2007/2008. The average purchase price in the period under analysis was 0.44 PLN per kg (Figure 1).

The volume of apples harvested is considered a key factor determining the purchase prices of apples for processing, because it affects the supply of apples for processing. In 2007 the yield of apples in Poland was very low due to frosts in early May, which significantly or completely destroyed flowers and fruit buds in some orchards. As the yield was very low, the prices paid to producers increased sharply [Nosecka 2007]. By contrast, in 2008, flower buds on fruit trees formed successfully and abundantly and there was no frost in the spring. This resulted in a high yield of fruits and a large supply of apples for processing in Poland. Due to the unfavourable economic situation on the global market of concentrated apple juice, apples for processing were purchased at very low prices [Nosecka 2008].

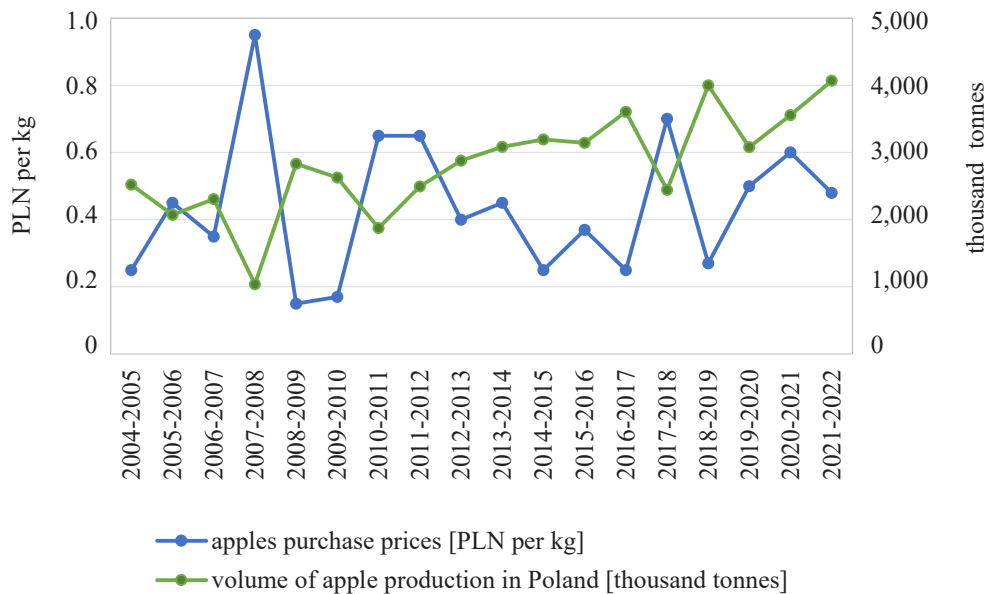


Figure 1. Purchase prices of apples for processing and volume of apple production in Poland between 2004/2005 and 2021/2022

Source: own calculations based on IERiGŻ-PIB data

DETERMINANTS OF PURCHASE PRICES OF APPLES FOR PROCESSING

Apart from the yield of apples in Poland, which is a decisive factor determining the purchase prices of apples for processing, the other potential determinants are (Table 1): the yield of apples harvested in the countries competing with Poland on the market of concentrated apple juice, i.e. in China, Republic of Moldova, Türkiye and Ukraine; the volume of production of concentrated apple juice in Poland; the export of apples from Poland; the export price of apples; the purchase price of apples for direct consumption paid by horticultural cooperatives; the Polish export and import of concentrated apple juice; the export and import prices of concentrated apple juice;

On the basis of the Pearson correlation coefficient, the factors which were significantly ($p < 0.05$) correlated with the dependent variable (the purchase price of apples for processing) were selected from the potential explanatory variables. These were the volume of apples harvested in Poland, the purchase price of dessert apples paid by horticultural cooperatives, the production of concentrated apple juice in Poland, the export of concentrated apple juice from Poland, the export price of apples, the export price of

Table 1. Dependent variable and the potential explanatory variables of the purchase prices of apples for processing in Poland between 2004/2005 and 2021/2022

| Item | Mean | SD | Correlation coefficient with dependent variable and (p) |
|---|--------|-------|---|
| Purchase price of apples for processing [PLN/kg] | 0.44 | 0.21 | n/a |
| Apple yield in Poland [thousand tonnes] | 2,823 | 757 | -0.5115 (0.0300) |
| Apple yield in China [thousand tonnes] | 35,770 | 7,034 | 0.0881 (0.7279) |
| Apple yield in Ukraine [thousand tonnes] | 997 | 241 | -0.0154 (0.9516) |
| Apple yield in Türkiye [thousand tonnes] | 2,931 | 683 | 0.1570 (0.5336) |
| Apple yield in Republic of Moldova [thousand tonnes] | 362 | 154 | -0.0144 (0.9546) |
| Purchase price of apples for direct consumption paid by horticultural cooperatives [PLN/kg] | 1.42 | 0.38 | 0.8755 (0.0000) |
| Production of concentrated apple juice in Poland [thousand tonnes] | 259 | 83 | -0.5397 (0.0207) |
| The Polish export of concentrated apple juice [thousand tonnes] | 234 | 61 | -0.6559 (0.0031) |
| Export price of concentrated apple juice [EUR/kg] | 1.15 | 0.28 | 0.8966 (0.0000) |
| Export of apples from Poland [thousand tonnes] | 776 | 289 | -0.4649 (0.0518) |
| Export price of apples [EUR/kg] | 0.34 | 0.07 | 0.7446 (0.0003) |
| The Polish import of concentrated apple juice [thousand tonnes] | 56 | 25 | 0.1831 (0.4669) |
| Import prices of concentrated apple juice [EUR/kg] | 0.84 | 0.26 | 0.8099 (0.0000) |

Source: own calculations based on IERiGŻ-PIB and FAOSTAT data

concentrated apple juice, and the import price of concentrated apple juice. These factors were used as a set of explanatory variables to estimate the econometric model.

ESTIMATION AND ASSESSMENT OF ECONOMETRIC MODEL

In order to identify the factors with significant influence on the purchase prices of apples for processing in Poland, multiple regression analysis was applied in the form of backward stepwise regression. The Statistica PL package was used for the statistical analysis. As a result, an econometric model with three explanatory variables was obtained: X_1 – export price of apples, X_2 – export volume of concentrated apple juice from Poland, X_3 – export price of concentrated apple juice (Table 2). The structural parameters of the

Table 2. Structural parameters of apples for processing purchase price model

| Explanatory variables and intercept | Coefficient | Standard error | t-Student | p |
|--|-------------|----------------|-----------|---------|
| Intercept | -0.07421 | 0.12511 | -0.59316 | 0.56253 |
| X_1 – export price of apples [EUR/kg] | 0.98430 | 0.28265 | 3.48235 | 0.00366 |
| X_2 – export of concentrated apple juice from Poland [thousand tonnes] | -0.00111 | 0.00029 | -3.76977 | 0.00207 |
| X_3 – export price of concentrated apple juice [EUR/kg] | 0.38540 | 0.08083 | 4.76763 | 0.00030 |

Source: own calculations based on IERiGŻ-PIB data

model indicated that all of the three explanatory variables were statistically significant at $p < 0.01$. The Fisher-Snedecor test showed that both the influence of the entire set of explanatory variables and the obtained regression coefficients were significant (Table 3).

The econometric model underwent substantive verification. The regression coefficient with the explanatory variable X_1 indicated that the increase in the export prices of dessert apples by 0.10 euros per kg was accompanied by an increase in the purchase prices of apples for processing by 0.098 PLN per kg. The increase in the export price of apples may result from the increasing demand for Polish apples abroad. When the demand for fruit for export increases, the amount of fruit available to domestic consumers and as a raw material for processing decreases. Therefore, when the supply of apples decreases in the winter and spring months, the processing industry must increase the purchase prices of apples for processing to acquire this raw material.

The negative value of the estimator of the X_2 variable suggests that the increase in the exports of concentrated apple juice from Poland by 10,000 tonnes was accompanied by a decrease in the purchase prices of apples for processing by 0.011 PLN per kg. The volume of concentrated apple juice production in Poland and the volume of concentrated apple juice exports are significantly and positively correlated with the volume of apples harvested in Poland². The volume of apples harvested in Poland was negatively correlated with the purchase price of apples for processing (Table 1). The increase in the volume of apples harvested was accompanied by a decrease in the purchase price of apples for processing. When there is a high volume of apples harvested, it is possible to acquire a large amount of raw material for processing, which enables the production and export of a large amount of concentrated apple juice. Therefore, the increase in the export of

² The correlation coefficient between the volume of apples harvested and the production of concentrated apple juice during the period under study amounted to 0.8205 ($p = 0.000$). The correlation coefficient between the volume of apples harvested and the export of concentrated apple juice amounted to 0.8215 ($p = 0.000$).

Table 3. The assessment of structural parameters of the model

| Item | Symbol | Model |
|--------------------------------|------------|-----------------------|
| Coefficient of determination | R^2 | 0.92573 |
| Adjusted R^2 | adj. R^2 | 0.90981 |
| Standard error | s_e | 0.06331 |
| The Fisher-Snedecor F-test (p) | F | 58.17008 (0.00000) |
| Variation estimator | v_e | 0.00914 |
| Mean Absolute Percentage Error | MAPE | 25% |
| Variance Inflation Factor | VIF | $X_1 = 1.76086$ |
| | | $X_2 = 1.36362$ |
| | | $X_3 = 2.22839$ |
| The Durbin-Watson test | d | 1.77875 |
| | dL | 0.93310 |
| | dU | 1.69614 |
| The Shapiro-Wilk test | W | 0.95635 |
| The Goldfeld-Quandt Test | F | 2.74886 |
| Run test | K_e | 9 |
| | K_1 | 5 |
| | K_2 | 14 |

Source: own calculations based on IERiGŻ-PIB data

concentrated apple juice was accompanied by a decrease in the purchase price of apples for processing (the negative value of the regression coefficient of the X_2 variable).

The positive value of the regression coefficient of the X_3 variable indicates that the purchase prices of apples for processing and the export price of concentrated apple juice followed the same trend. The increase in the export price of concentrated apple juice by 0.10 euros per kg was accompanied by an increase in the purchase prices of apples for processing by 0.038 PLN per kg. The high supply of concentrated apple juice and a certain level of demand for this product on the international market causes the need to offer a competitive price in order to attract customers. According to Bożena Nosecka [2017], Poland is a leader in the global production and export of concentrated apple juice due to the relatively low costs of production. The cost of the raw material (apples for processing) is an important element of the cost of production of concentrated apple juice. When the purchase prices of apples were low due to the high yield of these fruits in Poland, the export prices of concentrated apple juice also remained low, and vice versa – the high purchase prices of apples resulted in high export prices of concentrated apple juice.

The econometric model indicates a good fit of the regression function to the empirical data. The coefficient of linear determination was above 90%, which means that less than 10% of the variance in the purchase prices of apples for processing resulted from random fluctuations or the influence of factors not included in the model (Table 3). The standard error of the model was small, which means that the deviations of the actual purchase prices of apples for processing from the theoretical values estimated with the model amounted to 0.06 PLN per kg. The average deviation of the model residuals in relation to the average value of the time series was 0.9%. The average absolute percentage deviation showed that on average the residuals were 25% of the actual values. The level of the inflation variance factor indicated the lack of multicollinearity between the explanatory variables. The assessment of the properties of the random component revealed the lack of autocorrelation of the residuals of the econometric model, the normal distribution of the residuals, the lack of heteroskedasticity of the random component, and the correct form of the econometric model.

SUMMARY AND CONCLUSIONS

The study showed that the purchase prices of apples for processing in Poland were significantly influenced by the export prices of apples, the volume of the export of concentrated apple juice, and the export prices of concentrated apple juice. The increase in the export prices of apples may be caused by the growing demand for Polish apples on foreign markets, which may result in lower availability of apples for processing. Therefore, the increase in the export prices of apples was accompanied by the increase in the purchase prices of these fruits for processing.

The volume of export of concentrated apple juice depends on the volume of production of processed products, which is influenced by the volume of apples harvested in Poland. When there is a high volume of apples harvested, it is possible to acquire a large amount of the raw material for the production of concentrated apple juice. In consequence, there is a high supply and export of concentrated apple juice. However, they are negatively correlated with the purchase price of apples for processing. Therefore, the increase in the export of concentrated apple juice was accompanied by relatively low purchase prices of apples for processing. The level of export prices of concentrated apple juice was strongly related to the level of purchase prices of apples for processing and the increase of purchase prices of apples was accompanied by an increase in export prices of concentrated apple juice.

The estimated econometric model was statistically significant at a significance level of $p < 0.05$ and explained 90% of the variability of purchase prices of apples for processing. This means that the remaining part of the variability of the purchase prices was affected by the factors which were not included in the model.

The results of the study led to the following conclusions:

1. The production of apples for processing is coupled with the production of dessert apples. Therefore, when the purchase prices of apples for processing are decreasing and the profitability of fruit production is not guaranteed, producers should increase the share of apples intended for the dessert fruit market in the yield volume, especially those which are to be sold abroad.
2. An increase in the production of apples and concentrated apple juice in China, Ukraine, and Republic of Moldova, as well as the possibility for processing plants in Poland to acquire cheaper raw materials or semi-finished products from abroad, will result in a pressure to maintain low purchase prices of apples for processing in Poland.
3. Due to the increasing competition on the international market of concentrated apple juice, its producers in Poland will be forced to maintain the export price of concentrated apple juice at a competitive level. This will additionally result in relatively low purchase prices of apples for processing. In consequence, apple producers in Poland will have to maintain the costs of production of apples for processing at a low level. Due to technological progress, the harvesting of apples for processing is increasingly often mechanised, whereas the cost of manual harvesting is growing. This will additionally force producers to specialise only in apples for processing.

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CENY SKUPU JABŁEK DO PRZETWÓRSTWA W POLSCE I ICH DETERMINANTY

Słowa kluczowe: owoce do przetwórstwa, jabłka przemysłowe, produkcja jabłek, cena skupu, przetwórstwo owoców, cena eksportowa, zagęszczony sok jabłkowy

ABSTRAKT. Celem badań była identyfikacja istotnych determinant poziomu cen skupu jabłek do przetwórstwa w Polsce. Przedmiotem badań były ceny skupu jabłek przemysłowych opublikowane w półroczniku „Rynek owoców i warzyw” przez Instytut Ekonomiki Rolnictwa i Gospodarki Żywnościowej – PIB. Wyniki badań wskazują, że istotne były ceny eksportowe jabłek, wielkość eksportu zagęszczonego soku jabłkowego (ZSJ) i ceny eksportowe ZSJ. Wzrost cen eksportowych jabłek, wynikający na przykład z rosnącego popytu na polskie jabłka na rynkach zagranicznych, przy określonej podaży tych owoców, może skutkować mniejszą dostępnością jabłek przeznaczonych do przetwórstwa. Dlatego wzrostowi cen eksportowych jabłek towarzyszył wzrost cen skupu tych owoców do przetwórstwa. Wielkość eksportu ZSJ zależy od wielkości produkcji tych przetworów, na którą z kolei wpływa poziom zbiorów jabłek w Polsce. Wysokie zbiory jabłek były ujemnie skorelowane z ceną skupu jabłek przemysłowych. Dlatego wysokiemu eksportowi ZSJ towarzyszyły relatywnie niskie ceny skupu jabłek do przetwórstwa. Poziom cen eksportowych ZSJ był silnie i dodatnio skorelowany z poziomem cen skupu jabłek do przetwórstwa, a wzrostowi cen skupu jabłek przemysłowych towarzyszył wzrost cen eksportowych ZSJ.

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