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# Price volatility of milk and dairy products in Poland after accession to the EU

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**Abstract:** Milk and dairy products help meet the nutritional needs of the population. The main goal of this research was to analyse price volatility of milk and dairy products in Poland after accession to the European Union (EU). Price is the main economic influencer. We used 161 monthly observations from 01. 2007 to 05. 2020 to analyse the price changes. To measure the volatility, we have used Augmented Dickey-Fuller test (ADF test), Autoregressive-Moving-Average model (ARMA model), and Granger test. Our research confirmed high volatility of milk and dairy products prices. The ARMA model confirmed that the dairy product prices are stationary. Milk, butter and Gouda cheese are also useful for forecasting.

**Keywords:** factors; milk market; stationarity

Prices play a key role in the market. High prices of agricultural products are a problem for customers on one hand and good for food producers on the other. The prices of milk and dairy products in Poland are connected to changes in other EU countries, the United States of America (U.S.) and New Zealand. They have an impact on costs and obtained results (Rembeza and Seremak-Bulge 2006). Countries with large agricultural production like Poland have problems with price volatility of agricultural products. Prices have an impact on the decisions of consumers, intermediaries, and producers (Bórawski et al. 2020).

Prices are important in the milk market in Poland. Cow's milk production is very important in Poland since it accounted for 16% of its global agricultural receipts in 2017. Poland is a very important producer of milk. It takes the 5th position in the EU and 13th place in the world (Wilczyński et al. 2020). Most Polish milk producers have small dairy farms. The average area of dairy farms in the rural accountancy

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system was 22.5 ha in 2018. Such farms kept an average of 17 cows and obtained 5 748 kg of milk yield per year per cow (Milk Market 2020). These farms are small family businesses, which is the opposite of industrial farming, and have low negative impact on environment. According to Lagane (2014), the existence of large farms is undesirable because they create a threat to the environment even though they are more efficient than small farms.

The milk market has changed recently because of market fluctuations and changes in EU policy (Wierzejski et al. 2020). After integration, the EU milk market faced many challenges, such as production limits, greater sanitary regulations, and higher production costs. Polish milk producers fulfilled these requirements and became net exporters of milk and dairy products (Wysokiński et al. 2015).

Milk and dairy products are used in different homemade products. However, some consumers replace conventional milk products with vegetable products such as almond milk, soya milk, and coconut milk. These products have only a marginal market share and are relatively more expensive (Špička 2013).

The problems of dairy product price changes were analysed in Poland. The prices of milk and dairy products in the marketing chain are characterized by different dynamics. The asymmetry in prices transmission shows that the relations in one market depend on increasing or decreasing prices in different markets (Rembeza and Seremak-Bulge 2006). The prices paid to farmers have an impact on prices paid by consumers (Szajner 2017). The Polish milk market behaves similarly to other markets. The information confirms the impact on the prices throughout the marketing channel (Rembeza and Seremak-Bulge 2006). The changes in production costs influence the consumption by the same rate because of symmetric price transmission. The asymmetric changes imply different rates of influence on different levels.

The key factor is the identification of drivers shaping price transmission of non-perfect competition and the scattering of enterprises in the market. Intervention in the market can also create disturbances in the market (Ward 1982).

The literature describes the changes of milk and dairy products in the market and the transmission between different levels of prices (Conforti 2004; Popovics 2008). However, little attention is paid to price volatility of milk and dairy products. The intention of the paper is to fill in the scientific gap existing in the literature.

The aim of the research was to evaluate the changes in the prices of milk and dairy products in Poland. The detailed aims included:

– The evaluation of milk and dairy product prices;
– The analysis of milk and dairy products volatility;
– The measure the stationarity of milk and dairy products.

## MILK AND DAIRY PRODUCTS PRICE VOLATILITY

The integration of new member states into the EU in 2004 and 2007 resulted in changes in milk and dairy product prices. After 2004 there was a one-year stagnation, followed later by an increase in the prices of milk and dairy products in most EU countries (Lātečková et al. 2009).

Roman (2020) analysed the spatial integration in the prices on the milk market. Polish voivodeships differ in the long-term balance between milk prices. Market integration is influenced by different factors such as consolidation of production, regional specialization in milk production, and the abolition of milk quotas. Bórawski et al. (2020a) analysed the milk price changes in Poland in the context of the Common Agricultural Policy (CAP). The research found that the quota system guaranteed stable conditions for farmers and kept milk prices high. This system of an allocated quota was a marketing guarantee for farmers because their welfare depended on the regulations (Boulanger and Philippidis 2015; Alpman and Bitsch 2017). It had been expected that when the quota system would expire, the market would liberalize (Špička 2013), the number of dairy farms would drop and milk production would increase (Schönhart et al. 2012). After abolition of the system in 2015 the prices of milk fell.

However, after one year the prices of milk rose to adjust to higher prices on the international markets. The prices began to follow the prices in New Zealand and the U.S. (Szajner 2017; Parzonko and Bórawski 2020). After the abolition of the quota system, the price of milk and dairy products depended on supply and demand (Bórawski et al. 2020). The change has also influenced the industry structure including number of farms and milk processors, farm size distribution, land use and landscape in rural areas. The intensification of milk production with an increasing number of animals per hectare may lead to an increase in the amounts of nitrogen and phosphate, a threat to natural ecosystems (Buysse et al. 2012; Boere et al. 2015; Groeneveld et al. 2016).

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The EU agricultural policy in the dairy sector is based on elimination of milk production quotas at the national level, abolition of subsidies for export of dairy products outside the EU, and reduction of customs duties on imported dairy products into the EU. These policy changes contributed to increased competition on the EU milk market. The implemented agricultural policy results in the volatility of prices for dairy products and thus the purchase prices of milk. The so-called "milk package", which was to contribute to the stabilization of the milk market, fulfils its role only to a small extent (Parzonko 2020).

The market allows for spatial and vertical transmission signals. The process of price transmission can be affected by different factors such as (Conforti 2004):

– Transport and transaction costs between two locations and industries, which allows for more arbitrage and integration;
– Market power, which depends on the degree of concentration of the industry where price makers and price takers are common in the market;
– Increasing returns to scale in production where market power exists;
– Product homogeneity and differentiation that may affect price transmission and market integrity where similar goods are produced in different countries;
– Exchange rates where firms can discriminate prices between destinations;
– Border and domestic policies where trade policies affect spatial price transmissions and domestic policies have an impact on vertical and spatial price relations.

Market margins are the difference between consumer and producer prices. They can be described by a quantity and price structure. When the complementary goods and services are valued and added to a product, this can be described as the price structure (Koester 2020). The problem of agricultural commodity prices is discussed in the international literature as well. Grain price volatility is affected by supply and demand and spatial arbitrage (Santeramo et al. 2018).

## MATERIAL AND METHODOLOGY

The authors of the paper have performed a fourfold study and analysed the data for 161 months in 2007–2020 of prices of major dairy products – raw liquid milk, skimmed milk powder, Gouda cheese, and butter. The data was obtained from Milk Market (2020). The authors of the paper analysed the changes in milk and dairy products in Poland in the years 2007–2020.

In the first step of the analysis, the Augmented Dickey-Fuller test (ADF test) was used. This test was proposed in 1979 and is also called the unit-element test (Dickey and Fuller 1979). In practice, the existence of a unit root, i.e. the hypothesis, $r = 1$, is checked ($r$ – scalar random variable). The null hypothesis in the Dickey-Fuller test (DF test) claims the presence of the unit root, which means that the process is not stationary. If we reject $H_0$, we accept the alternative hypothesis $H_1$, that the unit root does not exist and the process is stationary (Bórawski et al. 2020).

$$y = py_{t-1} + u_t \tag{1}$$

where: $y_t$ – explanatory variable; $t$ – time index; $p$ – coefficient; $u_t$ – estimation error (white noise).

To achieve the goal, we used different tools such as the ADF test, Autoregressive-Moving-Average model (ARMA model), and the Granger test. To check the stationarity of the monthly time series of weighted average EU milk prices in the years 2007–2020, the Augmented Dickey-Fuller (ADF) test was used (Bórawski et al. 2020).

In the second step of the study ARMA models were used to analyse trends in prices of the main milk products prices. Their form is expressed as:

$$\begin{aligned} Y_t = {} & B_1 Y_{t-1} + B_2 Y_{t-2} + \ldots + B_p Y_{t-p} + \\ & + E_t + \theta_1 E_{t-1} + \theta_2 E_{t-2} + \ldots + \theta_q E_{t-q} \end{aligned} \tag{2}$$

where: $B$ – delay operator; $Y$ – analysed variable; $E$ – random component; θ – autoregression parameters; $q$ – amount of dalay (Bórawski et al. 2020).

The ARMA model can be used for prediction and is an excellent approach that can be used to specify and forecast. For this purpose, the autocorrelation function (ACF) and partial autocorrelation function (PACF) were processed (Bórawski et al. 2020). We have used 161 monthly observations so the number of series is large and the results can be considered important.

The third step was the performance of Pearson correlation, which led to the fourth step – the Granger causality test in order to check whether there is a visible dependence between milk product prices. The Pearson's correlation was conducted to measure the relationship between analysed variables. The Granger causality test is a statistical hypothesis test for determining whether one time series is useful for forecasting another.

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## RESULTS AND DISCUSSION

It is necessary to evaluate the changes in the milk channel because they reflect the changes in dairy processing sector which have high economic importance for the worldwide economy (Brian et al. 2015).

The efficiency of market channels is characterized by the relationship of prices between producers, and the wholesale and retail sectors. Milk prices in the marketing channel show changes not only in the long run, but also in shorter periods of time. Studies have found that retail prices of dairy products adjust faster to increases than decreases of farm prices (Weldesenbet 2013). Moreover, perfect price transmissions prevail in the long run and show a competitive market, whereas in a shorter period the transmissions may be asymmetric or incomplete, suggesting a non-competitive and imperfect market. We can conclude that imperfect transmission is when prices at the production stage are not transmitted properly to the consumer stage (Popovics 2008) (Figure 1).

Farmers on the one hand are engaged in the production of the necessary raw material for the dairy industry, and on the other hand, they are quite far away from the end consumer (Jarzębowski and Klepacki 2013).

As we can see from Table 1, the highest average prices for 1 kilogram were observed in butter (EUR 3.75), and Gouda cheese (EUR 3.30).

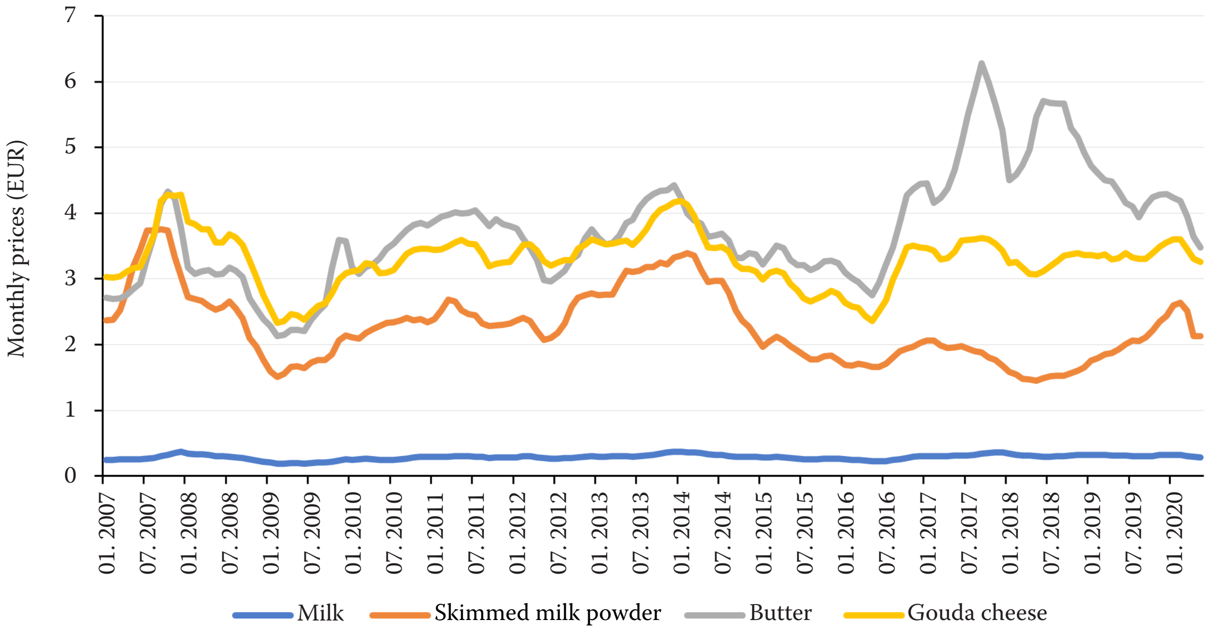


Figure 1. Monthly prices of main milk products in Poland in the years 2007–2020 (EUR)

The monthly exchange rate EUR/PLN in the period under study was adopted from Eurostat database
Source: Milk Market (2020)

Table 1. Descriptive statistics of monthly prices of milk and chosen milk products in Poland (01. 2007–05. 2020) (EUR)

| Variables | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|
| Raw milk | 0.29 | 0.04 | 0.19 | 0.37 |
| Skimmed milk powder | 2.28 | 0.55 | 1.45 | 3.76 |
| Butter | 3.75 | 0.83 | 2.13 | 6.28 |
| Gouda cheese | 3.30 | 0.41 | 2.33 | 4.28 |

Observations = 161
Source: Own study based on data milk market (Milk Market 2020)

Table 2. Augmented Dickey-Fuller test results of monthly prices of milk and chosen milk products in Poland (01. 2007–05. 2020)

| ADF test | *P*-value | |
|---|---|---|
| | without trend | with trend |
| Raw milk | 0.039 | 0.020 |
| Skimmed milk powder | 0.049 | 0.014 |
| Butter | 0.034 | 0.010 |
| Gouda cheese | 0.007 | 0.023 |

ADF test – Augmented Dickey-Fuller test
Source: Own study based on data milk market (Milk Market 2020)

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The very important elements are the economic condition of the dairy processor purchasing milk from farmers, the type of dairy products produced, and the territorial scope of the market. In the case of a good financial condition of dairies, especially those owned by farmers (cooperatives) and producing dairy products sold mainly on the local market, the impact of the situation on the global market is much smaller than in the case of other entities. Nevertheless, it should be remembered that milk production in Poland significantly exceeds internal consumption (both human consumption and use for feed).

The Augmented Dickey-Fuller test (ADF test) showed that the time series of weighted average raw milk prices, skimmed milk powder, butter, and Gouda cheese were stationary (*P*-values were under 0.05, Table 2).

We have used the ARMA model to check if dairy product prices depend on previous values (Table 3). The next step was to check how many lags should be taken into account when constructing the ARMA

Table 3. Autoregressive-Moving-Average (ARMA) estimation for monthly milk prices of milk and chosen milk products in Poland (01. 2007–05. 2020)

| Specification | Coefficient | SE | *z* | *P*>/*z*/ | 95% Confidence interval | |
|---|---|---|---|---|---|---|
| **Raw milk** | | | | | | |
| Constants (cons) | 118.70 | 6.85 | 17.32 | 0.000 | 105.26 | 132.13 |
| Autoregression (Ar) | | | | | | |
| Likelihood (L1) | 1.56 | 0.08 | 19.38 | 0.000 | 1.40 | 1.71 |
| Likelihood (L2) | –0.59 | 0.08 | –7.60 | 0.000 | –0.74 | –0.44 |
| Moving (Ma) | | | | | | |
| Likelihood (L1) | 0.16 | 0.10 | 1.56 | 0.120 | –0.04 | 0.35 |
| Sigma | 2.43 | 0.12 | 20.09 | 0.000 | 2.19 | 2.67 |
| **Skimmed milk powder** | | | | | | |
| Constants (cons) | 9.39 | 0.88 | 10.65 | 0.000 | 7.66 | 11.12 |
| Autoregression (Ar) | | | | | | |
| Likelihood (L1) | 1.50 | 0.10 | 14.74 | 0.000 | 1.30 | 1.69 |
| Likelihood (L2) | –0.54 | 0.10 | –5.35 | 0.000 | –0.74 | –0.34 |
| Moving (Ma) | | | | | | |
| Likelihood (L1) | 0.20 | 0.13 | 1.56 | 0.120 | –0.50 | 0.46 |
| Sigma | 0.32 | 0.01 | 26.22 | 0.000 | 0.29 | 0.34 |
| **Butter** | | | | | | |
| Constants (cons) | 15.20 | 1.57 | 9.64 | 0.000 | 12.11 | 18.29 |
| Autoregression (Ar) | | | | | | |
| Likelihood (L1) | 1.44 | 0.11 | 12.99 | 0.000 | 1.22 | 1.66 |
| Likelihood (L2) | –0.48 | 0.11 | –4.58 | 0.000 | –0.69 | –0.28 |
| Moving (Ma) | | | | | | |
| Likelihood (L1) | 0.22 | 0.16 | 1.14 | 0.160 | –0.09 | 0.53 |
| Sigma | 0.65 | 0.02 | 26.53 | 0.000 | 0.60 | 0.69 |
| **Gouda cheese** | | | | | | |
| Constants (cons) | 13.56 | 0.43 | 31.41 | 0.000 | 12.72 | 14.41 |
| Autoregression (Ar) | | | | | | |
| Likelihood (L1) | 1.59 | 0.09 | 16.84 | 0.000 | 1.40 | 1.77 |
| Likelihood (L2) | –0.64 | 0.09 | –7.11 | 0.000 | –0.82 | –0.47 |
| Moving (Ma) | | | | | | |
| Likelihood (L1) | –0.02 | 0.14 | –0.14 | 0.890 | –0.29 | 0.26 |
| Sigma | 0.32 | 0.13 | 23.28 | 0.000 | 0.29 | 0.34 |

Source: Own study based on data milk market (Milk Market 2020)

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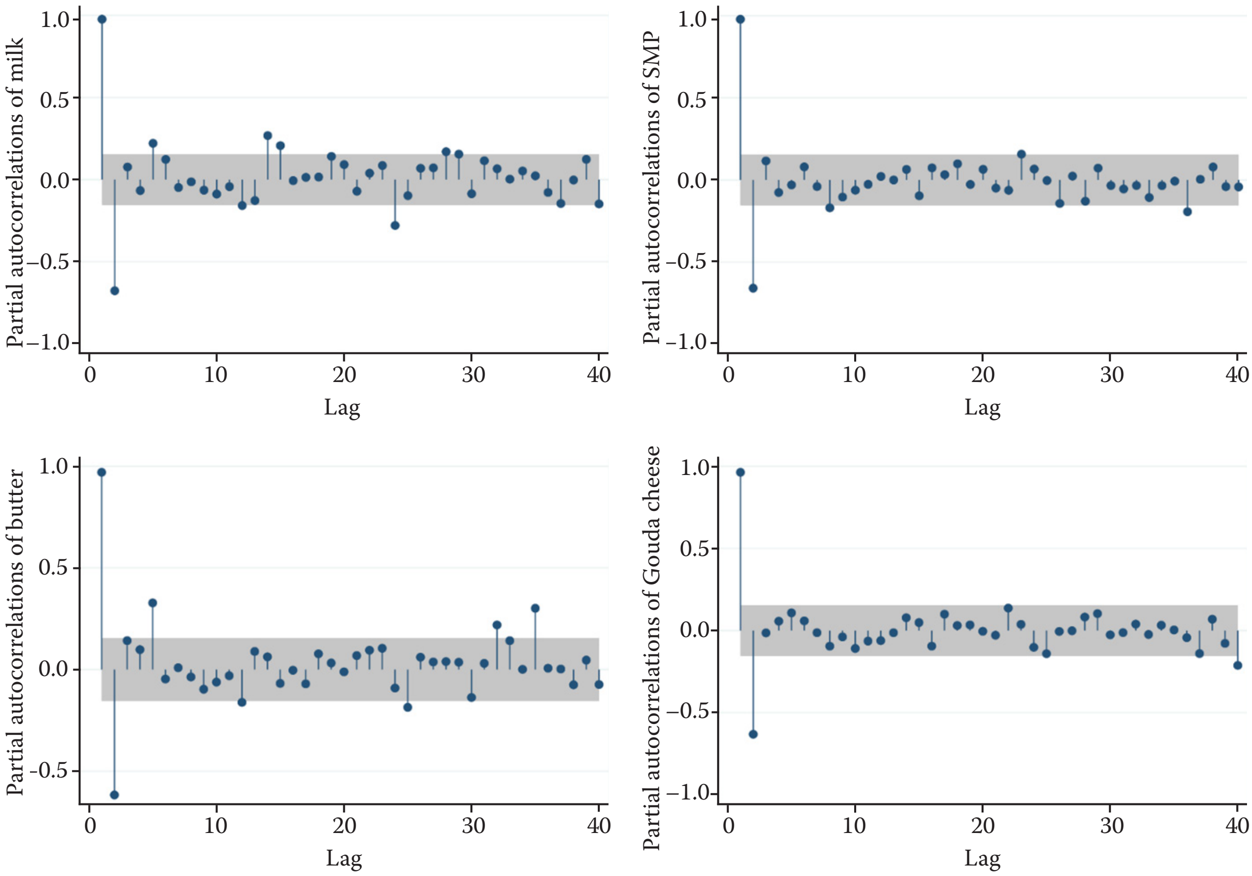


Figure 2. Partial autocorrelations functions (PACF) of prices of milk and chosen milk products in Poland (01. 2007–05. 2020)

SMP – skimmed milk powder; 95% confidence bands [se = 1/swrt(n)]
Source: Own study based on milk market data (Milk Market 2020)

model. The ACF function computes (and by default plots) estimates of the autocovariance or autocorrelation function. PACF is the function used for the partial autocorrelations (Figure 2).

High prices of milk help to obtain an advantage in the sales market, gather market share or market leader (Simo et al. 2016). However, in recent years we could observe changes in processing, production of, and trade in milk and dairy products which were the effects of the Common Agricultural Policy (CAP) and market failure. Milk processing enterprises are an important agro-food sector and an unstable situation can create difficult situation in the market.

The instability of the economic environment has affected price levels, which fluctuate and create price transmission in the supply chain. The milk and dairy products prices show the differences between farmers, producers, retailers, and consumers. To evaluate these changes, it is necessary to create cointegration models that verify asymmetric price transmission (Abdallah et al. 2020).

In 1970, Box and Jenkins (1970) created ARMA models using methodology involving an iterative three-stage process of model selection, parameter estimation, and model checking. This model has been used in many areas of time-series forecasting such as linear prediction, system identification, and spectral analysis (Rojas et al. 2008). It is not an easy task to build an ARMA model because it requires training in statistical analysis, and a good knowledge of the field of application.

Our analysis confirms sizable differentiation in the results of the ARMA model (Table 3). The developing process of milk and dairy products prices is considered to be a linear process and is adequately captured by the conditional mean ARMA. In this case, the results from the ARMA model are counted as white noise processes (i.e., mean zero and constant variance).

Skimmed milk powder, butter, and Gouda cheese are the main products prepared from raw milk. These products are processed from raw milk for consumption.

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In the production phase, exacting requirements for food safety involve a process of transformation of raw milk to milk products to be prepared during milk processing (Xu and Flapper 2009). The production phase of the transformation to products from raw milk is not the only important process. In the milk market the price correlations are important, too.

As we can see from Table 4, the highest correlation was observed between raw milk and Gouda cheese (0.8650) and butter (0.7994). The Gouda cheese price is also strongly correlated with the skimmed milk powder price. The smallest correlation is between milk powder and butter (0.0659).

Our analysis confirmed that the raw milk price is useful for forecasting skimmed milk powder, butter, and Gouda cheese prices.

The null hypothesis should be rejected at the regular 5% level as the associated *P*-value is lower than 0.05. Butter and Gouda cheese prices are also useful for forecasting milk and skimmed milk powder prices (Table 5).

The skimmed milk powder price is not useful in forecasting prices for milk, butter and Gouda cheese. The null hypothesis should not be rejected at the regular 5% level as the associated *P*-value is as high as 0.680 (way above 0.05).

It is important to analyse the milk and dairy price changes in Poland in the context of the EU, U.S., and New Zealand. Average prices offered by dairies in the EU, U.S., and New Zealand slightly differed in 2015–2018. However, a different pace in the monthly fluctuations in the purchase price of milk should be noticed. In the first half of 2018, prices were levelling off in New Zealand and European dairy markets. In the second half of 2018 (from September), the purchase price of milk in New Zealand began to decline, while for EU dairies it remained at the same level. Taking into account the formed dependencies between the milk market in New Zealand, the U.S. and the EU, a drop in the purchase prices of milk can be expected in EU dairies. The pace may be slightly slower due to the drought in Europe in 2018 (Parzonko 2020).

Table 4. Pearson's correlation coefficient of prices of milk and chosen milk products in Poland (01. 2007–05. 2020)

| Specification | Raw milk | Skimmed milk powder | Butter | Gouda cheese |
|---|---|---|---|---|
| Raw milk | 1 | – | – | – |
| Skimmed milk powder | 0.302 | 1 | – | – |
| Butter | 0.799 | 0.066 | 1 | – |
| Gouda cheese | 0.865 | 0.601 | 0.650 | 1 |

Source: Own study based on data milk market (Milk Market 2020)

Table 5. Granger causality Wald tests

| Equation | Excluded | Chi$^2$ | d*f* | Probability > chi$^2$ |
|---|---|---|---|---|
| Milk | skimmed milk powder | 5.300 | 2 | 0.071 |
| | butter | 34.207 | 2 | 0.000 |
| | Gouda cheese | 7.157 | 2 | 0.028 |
| | all | 73.755 | 6 | 0.000 |
| Skimmed milk powder | milk | 0.067 | 2 | 0.967 |
| | butter | 0.700 | 2 | 0.704 |
| | Gouda cheese | 0.684 | 2 | 0.710 |
| | all | 3.973 | 6 | 0.680 |
| Butter | milk | 7.339 | 2 | 0.025 |
| | skimmed milk powder | 2.610 | 2 | 0.271 |
| | Gouda cheese | 0.513 | 2 | 0.774 |
| | all | 13.059 | 6 | 0.042 |
| Gouda cheese | milk | 2.109 | 2 | 0.348 |
| | skimmed milk powder | 20.897 | 2 | 0.000 |
| | butter | 17.994 | 2 | 0.000 |
| | all | 31.808 | 6 | 0.000 |

Source: Own study based on data milk market (Milk Market 2020)

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## CONCLUSION

After accession to the EU, the prices of milk and dairy products in Poland changed. This was the effect of access to the Common Market of the EU, which greatly increased the number of customers for Polish dairy products.

The volatility of Polish milk prices is higher at the farm level. It demonstrates the scope of changes and their direction. The average prices paid to farmers have an impact on the prices of dairy products, particularly retail prices of drinking milk, natural yogurt prices, and prices of processed cheese.

Our research proved that the raw milk price is useful for forecasting skimmed milk powder, butter, and Gouda cheese prices. These results demonstrate the links between milk prices at different levels. Low prices of raw milk are important for the competitiveness of the milk market. They have an impact on the prices of other dairy products and exports.

The ARMA model confirms the cohesion between milk and dairy products prices and their previous values. It proves the correlation between prices in the market.

The demand for milk and dairy products is negatively price inelastic and more dependent on income. Our regression analysis confirms that average monthly expenses for food per 1 person determine butter prices, the prices of 30% fat cream, and natural yogurt prices. These findings can be essential for policy makers in the EU because the CAP depends on the development of demand for dairy products (Bouamra-Mechemache et al. 2008).

In recent years, the prices of milk and dairy products in Poland have been shaped by the EUR/PLN exchange rate and exports of milk and dairy products. This is because most of the milk and dairy products are sold in the EU domestic market and only 10% go outside the EU. That is why the exports became one of the most important elements of the milk and dairy products market.

The elimination of the quota system in 2015 and the lack of EU regulations and national policy stabilizing the purchase prices of milk over time force processors (dairies) to actively participate in the process of even deeper cooperation between farmers and processors. In order to do this, good information mechanisms are needed. Processors need to quickly share information with farmers and farmers have to share information about their production and planned investment activities, which is in line with recommendations of other authors (Parzonko 2020).

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