https://doi.org/10.17221/61/2021-AGRICECON

Price changes of dairy products in the European Union

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Citation: Bełdycka-Bórawska A., Bórawski P., Guth M., Parzonko A., Rokicki T., Klepacki B., Wysokiński M., Maciąg A., Dunn J.W. (2021): Price changes of dairy products in the European Union. Agric. Econ. – Czech, 67: 373–381.

Abstract: This article presents changes in the prices of milk and other dairy products in the European Union (EU). First, the descriptive statistics of the prices of milk and dairy products are presented, and then correlation and regression analyses were conducted to measure the relationships between the prices. We used the augmented Dickey-Fuller (ADF) test and generalised autoregressive conditional heteroscedasticity (GARCH) model to measure the stationarity and changes in dairy product prices in the EU. At the EU level, we checked the changes in prices of butter, skim milk powder, whole milk powder, Cheddar, Edam, Gouda, Emmental and whey powder. Our analysis confirmed that the butter, skim milk powder, whole milk powder, Cheddar, Edam and Gouda processes depend on previous values. The biggest price changes were observed in whey powder (34.12%), butter (24.46%) and skim milk powder (21.78%).

Keywords: butter; GARCH model; skim milk powder; whey powder

Milk and dairy products are basic items in the human diet. Milk contains many essential nutritional ingredients such as microelements, calcium, vitamins and minerals (Simo et al. 2016). High volatility in the prices of milk and dairy products can affect the population of the entire world. That is why factors shaping milk and dairy product prices are of interest in agricultural economics.

The challenges of factors shaping milk and dairy product price changes have been described in the international literature (Simo et al. 2016; Abdallah et al. 2020). Moreover, processors of dairy products have stronger market positions than do farmers because the price changes affect mainly farmers, and an individual processor is larger compared to the market than an individual farmer is (Abdallah et al. 2020).

Supported by the National Science Centre in Poland (Project OPUS 15, Project No. 2018/29/B/HS4/00392).

https://doi.org/10.17221/61/2021-AGRICECON

As a result of improved genetics and nutrition, intensification of milk production has increased for many years in European Union (EU) countries (Skarżyńska and Jabłoński 2016). An increase in milk yield and a decrease in cow numbers are expected in the future (Skarżyńska and Abramczuk 2017).

The efficiency of milk production can be increased by cost decreases and the use of milk facilities (Tauer and Mishra 2006). Moreover, inefficient farmers have low milk production, higher labour costs and overinvestment (Stokes et al. 2007).

The integration of the new member states in 2004 (Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia) and 2007 (Bulgaria and Romania) also affected the production and prices of milk and dairy products. The prices and production of these products increased because of access to the Common Market (Simo et al. 2016). Moreover, milk production is diversified in the EU, which is one reason for the intra-EU trade of milk and dairy products. Only a few countries, such as France, Germany, Italy, the Netherlands, and Poland, have large annual production and a prominent role in shaping the market situation (European Commission 2016; Skarżyńska and Jabłoński 2016).

Milk is transformed into different products – for example, butter, skim milk powder, whole milk powder, Cheddar, Edam, Gouda, Emmental and whey powder. Because of price changes in milk and dairy products, we investigated the factors determining them. Milk derives its value from the dairy products produced. Butterfat, solids-not-fat and water from milk are used in dairy products. The implicit values come from the retail market for dairy products or from farm to dairy processors (Gillmeister et al. 1996).

The issue of price volatility has been described in the literature. For example, Rosa et al. (2016) investigated dairy commodity prices. They found that Italy faced moderate milk volatility because the market was protected from the world market by a quota system. The increase in milk supply after 2015 when the quota system was abolished resulted in a decrease in the raw milk price.

The dairy sector is very important in the EU because it is characterised by 12 000 processing facilities, 300 000 jobs and 600 000 dairy farms. Most of the milk and dairy products are consumed in the EU (87%), and the rest is exported (Buleca et al. 2018).

It is widely believed that the Common Agricultural Policy (CAP) for the milk market affects the market directly and prices indirectly. Previously, the dairy sector was under a quota system that regulated milk production. After its abolition in 2015, the prices on the market were determined by supply and demand forces. The elimination of the quota system and a decrease in customs duties created stronger competition in the milk market. The prices on the EU market started to follow the prices on the New Zealand and the United States milk and dairy products markets (Parzonko 2020). After the elimination of the quota system, the prices for milk that were paid to farmers became the most important element of the market shaping the production of milk and dairy products. Milk production developed well in countries and regions that met the requirements of the common market and were competitive (Bórawski et al. 2020b). The abolition of the quota system was accompanied by the abolition of the Target Price and the introduction of the Single Payment Scheme. The EU's dairy policy created fairly similar milk prices throughout Europe (Katrakilidis 2008). The quota system was not effective because it limited expansion, which resulted in a decrease in cow numbers in many countries (Binfield et al. 2008).

Another factor shaping dairy product prices is consumption. According to Organisation for Economic Cooperation and Development data, average consumption of fresh dairy products decreased between 2004 and 2018 from 94.52 kg per capita to 88.17 kg per capita in the EU (a decline of 6.7%). In 2018, butter consumption in the EU was 4.33 kg per capita, which was higher than in 2004 (3.57 kg). From 2004 to 2018, the consumption of cheese increased from 16.53 kg per capita to 19.01 kg per capita, and skim milk powder increased from 1.11 kg per capita to 1.35 kg per capita (Milk Market 2020). Milk consumption increased by 25% in the years from 2004 to 2017 from 174 L per capita to 218 L per capita in Poland; furthermore, the consumption of butter increased from 4.4 kg to 4.5 kg in the analysed period (Bórawski et al. 2020a). Not all countries observed the increase in milk consumption. The United States does not have quotas. In the United States, consumption of milk decreased from 81 kg per capita to 66 kg per capita during the period from 2009 to 2018. At the same time, the consumption of all dairy products increased from 276 kg per capita to 293 kg per capita. This situation in dairy product consumption in the United States has policy implications for farmers and dairy processors (Ramirez et al. 2006).

Milk and dairy product prices have seasonal characteristics. The seasonality of prices is due to seasonal production. The prices of milk and dairy products remain high in autumn and winter and decrease in spring and summer (Kussaiynor and Zhakupova 2019).

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According to Lajdová and Bielik (2013), dairy product prices adjust more to an increase in the farm price than to a decrease. In addition, farm prices are more elastic in response to a shock in retail prices. Symmetric changes mean that the retail prices react quickly to a rise in farm price and also to a drop in farm price (Stewart and Blayney 2011). Asymmetric price transmission means that prices are more responsive when the price margin is increased than decreased (Kharin 2018).

Milk is produced on dairy farms and then is stored and collected by dairy cooperatives (Setianti et al. 2017). The effective management of the process of collecting, transporting, and storing milk is important because it may reduce the risk of loss. Moreover, it has an effect on milk prices because good connections between farmers and cooperatives can reduce market imperfections.

The milk sector was integrated into the Common Market Organisation for agricultural products in 2013. However, the policy instruments for milk date back to 1960s. High support levels, high prices and intervention buying were the main measures to encourage production. In time, the goals of the CAP, mainly self-sufficiency, high prices and a decent standard of living for farmers, were reached, and support policies in the dairy sector led to a substantial rise in production (Yilmaz 2017).

Cow milk production is a strategic activity, not only in the United States but also in the EU and other parts of the world. It supports processing enterprises that employ people. Milk production is important not only for agriculture but also for the processing business and trade. Cow milk production represents the majority of milk production and dairy products (Simo et al. 2016).

The main aim of our research was to recognise factors shaping the prices of dairy products in the EU. To achieve this goal, we wanted to answer following questions:

i) What is the stationarity of dairy products in the EU?

ii) How have the prices of dairy products changed in the EU?

MATERIAL AND METHODS

To check the price changes in dairy products in the EU, we have presented the data from 01. 01. 2001 to 27. 01. 2019 (943 weekly observations). We obtained the data from the European Milk Market (2020), which collects weekly data for EU dairy product prices. These prices are calculated as an average of national prices of dairy products. The prices of dairy products from individual countries were not available. The database presents average EU dairy product prices.

The data helped to examine the changes for the entire EU. We checked the changes in the following EU dairy products: butter, skim milk powder, whole milk powder, Cheddar, Edam, Gouda, Emmental and whey powder (Bórawski et al. 2020b).

First, we conducted an augmented Dickey-Fuller (ADF) test to see whether the price variables were non-stationary (Lajdová and Bielik 2013). The unit root is an example of non-stationarity (Kharin 2018). Using the ADF test, we checked two hypotheses. The null (first) hypothesis was that the unit root is present in a time series. The alternative (second) hypothesis was that there is no unit root and the time series is not stationary.

Finally, we calculated generalised autoregressive conditional heteroscedasticity (GARCH) models that were elaborated by Engle (1982) and Bollerslev (1986) to analyse the time series. The models are widely used for risk management, and they can capture both volatility clustering and unconditional return distribution (Teresienė and Dubauskas 2008):

$$\sigma_t^2 = \alpha_0 + \alpha_1 y_{t-1}^2 + \beta_1 \sigma_{t-1}^2 \tag{1}$$

where: σ_t^2 – conditional variance on information at time t–1; α_0 – one-period ahead forecast variance based on past information (called the 'conditional variance'); y_{t-1}^2 – lagged squared residuals from the conditional mean equation with the non-negativity restrictions $L_0 > 0$; β – influence of past volatility on the current volatility σ_{t-1}^2 – last period's forecast variance.

In the GARCH notation, the first subscript refers to the order of the y^2 terms on the right side, and the second subscript refers to the order of the σ^2 terms (Bollerslev 1986). GARCH is used to analyse conditional variance. The process of variance is not stationary (Teresienė and Dubauskas 2008).

Changes in dairy product prices can be described with autoregression (AR(*p*) – GARCH(1, 1)):

$$y_t = \phi_0 + \sum_{i=1}^{p} \phi_i y_{t-i} + e_t \tag{2}$$

$$e_t \left| \psi_{t-1} \sim t\left(\upsilon, 0, h_t\right)\right. \tag{3}$$

$$h_t = \alpha_0 + \alpha_1 e_{t-1}^2 + \beta_1 h_{t-1} \tag{4}$$

where: y_t – dependent variable; e_t – interference or error variable; ψ_{t-1} – series history up to time t – 1; $t\left(\upsilon, 0, h_t\right)$ – Student t distribution with υ degrees of freedom

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($\upsilon > 2$); h_t – conditional variance; given the regularity conditions $\alpha_0 > 0$, $\alpha_1 \geq 0$, and $\beta_1 \geq 0$, the required stationarity condition is $\alpha_1 + \beta_1 < 1$.

Also, because of the presence of autocorrelation, the roots of the polynomial $z^p - \phi_1 z^{p-1} - \phi_2 z^{p-2} - \ldots - \phi_p = 0$ lie inside the unit circle. According to the GARCH models, the residual depends on the previous period's mean and variance (Daryanto et al. 2020). The GARCH model can satisfactorily explain the volatility of the analysed series (Hossain 2018).

RESULTS AND DISCUSSION

Raw cow milk prices in the EU changed during the period from 2001 to 2019 (Table 1). The smallest average values were found in Romania (EUR 27.14/100 kg), Poland (EUR 27.49/100 kg), Slovakia (EUR 28.15/100 kg) and the Czech Republic (EUR 28.84/100 kg).

The highest raw cow milk prices were in Cyprus (EUR 49.94/100 kg), Malta (EUR 48.08/100 kg), Greece (EUR 39.65/100 kg) and Finland (EUR 39.54/100 kg). These same countries achieved the highest prices for raw cow milk: Cyprus (EUR 58.86/100 kg), Malta (EUR 56.07/100 kg), Finland (EUR 49.50/100 kg) and Greece (EUR 47.39/100 kg).

The lowest minimum values were in Lithuania (EUR 11/100 kg), Latvia (EUR 12.98/100 kg), Poland (EUR 14.60/100 kg) and Slovakia (EUR 17.68/100 kg).

The research conducted by Roman and Roman (2020) indicated that milk prices in Poland were lower than in other EU countries. The Polish milk market is stronger and more integrated than it was before joining the EU. The prices of milk in Poland affect prices in other countries, such as Estonia, Latvia, and the Czech Republic. Polish milk and dairy product prices depend on prices from Germany, Ireland, France, and Slovakia because most Polish dairy product exports go to these countries.

The prices of milk and dairy products in the EU are determined by various factors, such as abolition of the milk quota in the EU and the liberalisation of the dairy market. The prices adjust to end points of a supply chain, which are retail prices and farm prices. The transmission is described by changes in prices from one end to the other. Dairy farmers are disadvantaged when farm milk prices decrease with little evidence of a corresponding change in retail prices (Stewart and Blayney 2011).

Numerous factors affect milk and dairy products. Generally, the prices are the result of conditions in the European and world markets, costs incurred, milk production, CAP, food safety and other factors.

Table 1. European cow's raw milk prices in the 2001–2019 (EUR/100 kg)

Country	Average	Max.	Min.
Austria	33.65	42.70	25.27
Belgium	30.72	43.20	20.78
Bulgaria	29.79	37.02	20.78
Croatia	32.71	37.76	27.89
Cyprus	49.94	58.86	35.99
Czech Republic	28.84	38.30	21.12
Denmark	33.13	43.50	25.38
Estonia	27.60	40.33	17.54
Finland	39.54	49.50	30.73
France	32.24	39.82	23.58
Germany	31.63	42.46	22.00
Greece	39.65	47.39	28.32
Hungary	27.88	36.87	19.80
Irleand	32.04	45.40	21.83
Italy	35.35	41.79	29.02
Latvia	24.83	35.15	12.98
Lihtuania	24.09	37.00	11.00
Luxembourg	32.57	46.42	23.69
Malta	48.08	56.07	41.82
Netherlands	33.03	45.09	21.56
Poland	27.48	37.17	14.60
Portugal	30.96	39.50	26.20
Romania	27.14	33.78	18.46
Slovakia	28.15	36.88	17.67
Slovenia	29.10	37.29	23.16
Spain	31.61	45.10	26.85
Sweden	33.61	42.52	23.48
United Kingdom	30.26	40.01	21.79
Weighted average EU	31.88	40.21	24.39

Source: Own elaboration on the basis of the milk market (Milk Market 2020)

Dairy farmers are price takers, so the price at the farm level adjusts to the prices of dairy product. These results are confirmed by the findings of Lajdová and Bielik (2013) who claim that the market power of the dairy industry is on the demand side.

The abolition of the quota system in 2015 allowed milk and dairy product price volatility and an increase in production (Rezitis and Stavropoulos 2010). It enhanced the problem of pollution from excessive nitrates and phosphates. The issue of greenhouse gas emission reduction with the increase in milk production should be a priority (Kelly et al. 2012).

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Figure 1 shows the changes in dairy product prices in the EU. The biggest increase was observed in 2008 and the biggest decrease in 2015. This finding means that dairy product prices are vulnerable to changing conditions in the market and the economy. The elimination of the quota system in 2015 changed the market conditions for milk and dairy product producers, and the EU milk market was opened for international markets. The quota system, however, had not protected prices against the sharp fluctuations of milk and dairy products.

Results of our analysis helped confirm that the highest average prices were in Emmental, which is a cow milk cheese (Table 2). The descriptive statistics show the changes that took place in dairy products in the EU. The coefficient of variation measures the changes that occurred. The biggest changes were in whey powder (34%), butter (24%) and skim milk powder (22%).

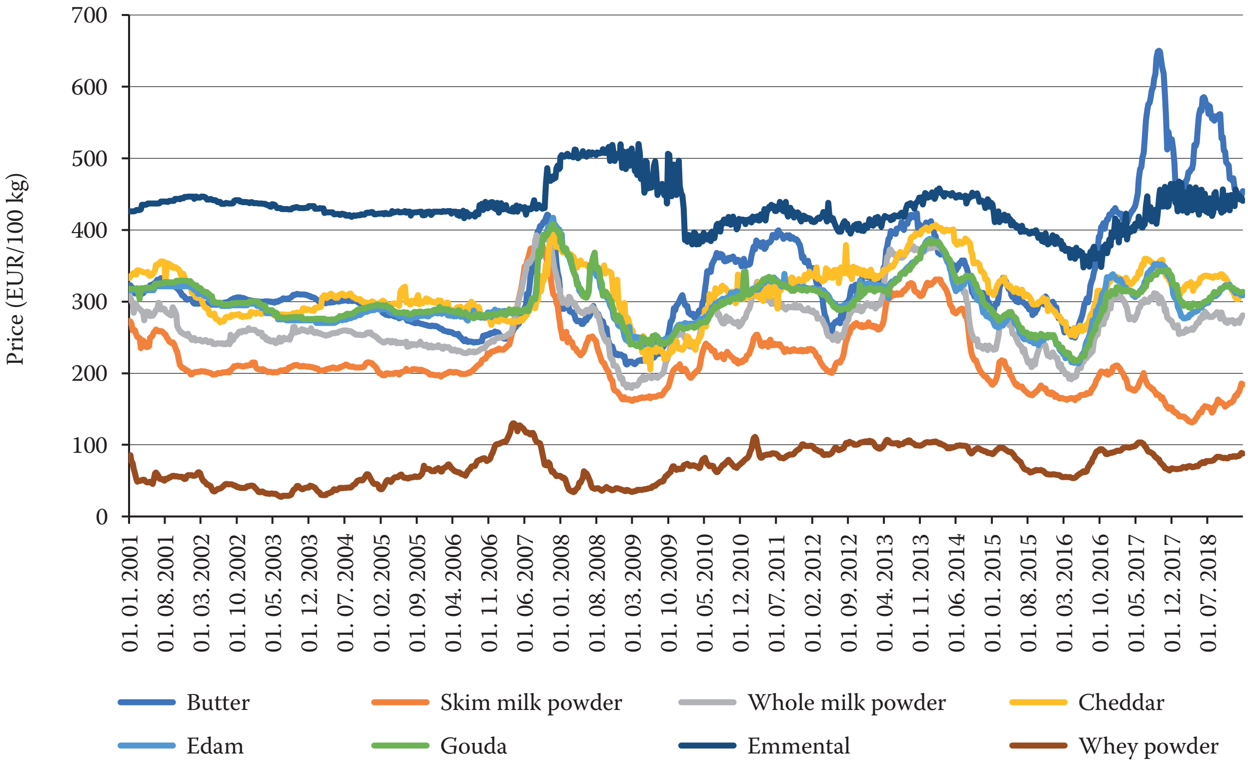

Figure 1. Prices of dairy products in the EU

Source: Own elaboration on the basis of the milk market (Milk Market 2020)

Table 2. Descriptive statistics of prices of dairy products in the EU in the years 2001–2019

Variable	Average	Median	Min.	Max.	SD	Coefficient of variation	Skewness	Kurtosis
	(EUR/100 kg)							
Butter	332.38	304.44	212.04	650.08	81.287	24.456	1.4642	2.249
Skim milk powder	218.52	207.78	131.30	385.36	47.604	21.785	1.1061	1.339
Whole milk powder	269.78	259.89	179.45	392.80	43.048	15.957	0.7450	0.674
Cheddar	313.73	311.67	205.19	406.90	37.844	12.063	0.0893	0.004
Edam	299.28	294.77	213.71	416.98	34.858	11.647	0.4331	0.629
Gouda	300.64	297.78	217.23	408.19	33.990	11.306	0.3577	0.620
Emmental	430.38	427.86	347.64	519.93	30.473	7.080	0.6161	1.204
Whey powder	70.07	68.50	27.50	130.00	23.907	34.117	0.1058	–1.051

Source: Own elaboration on the basis of the milk market (Milk Market 2020)

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Table 3. Correlation analysis between dairy products prices

Specification	Butter	Skim milk powder	Whole milk powder	Cheddar	Edam	Gouda	Emmental	Whey powder
Butter	1.0000	–0.0028	0.5463	0.4832	0.5166	0.4927	–0.1220	0.3918
Skim milk powder	–	1.0000	0.8075	0.4856	0.6197	0.6040	0.1100	0.4604
Whole milk powder	–	–	1.0000	0.7162	0.8301	0.8082	0.0520	0.5681
Cheddar	–	–	–	1.0000	0.7931	0.8154	0.1741	0.3999
Edam	–	–	–	–	1.0000	0.9810	0.2932	0.3730
Gouda	–	–	–	–	–	1.0000	0.3526	0.3270
Emmental	–	–	–	–	–	–	1.0000	–0.3270
Whey powder	–	–	–	–	–	–	–	1.0000

Source: Own elaboration on the basis of milk market (Milk Market 2020)

Smaller price changes were observed in whole milk powder (16%) and Cheddar (12%).

Skewness describes the asymmetry of distribution around its mean. When the skewness is near zero, the distribution of the data is symmetric. When the skewness is positive, the distribution with an asymmetric tail is close to a positive value. Negative skewness has the opposite meaning (Čisar and Čisar 2010). The skewness values were positive.

We also analysed kurtosis, which describes the peakedness or flatness of a distribution. When the kurtosis is equal to zero, the time series has a normal distribution of data. Only whey powder had negative kurtosis in our analysis.

Table 3 shows that the correlation was positive in most cases. A negative correlation was found between butter and Emmental and between butter and skim milk powder. Whey powder was also negatively correlated with Emmental. The negative correlation indicates that when whey powder price increases, the Emmental price decreases, and *vice versa*.

The ADF test examines the stationarity of dairy product prices. When the time series is stationary, it has a finite mean. Moreover, prices fluctuate around a constant long-run mean. A stationary series is described by a finite variance (Hossain 2018).

We tested the null hypothesis that the time series has a unit root and is not stationary (Table 4). According to Stewart and Blayney (2011), the test is applied to a variable and then to its differences until a stationary series is identified. The highest *P*-value was observed in butter, whey powder and Emmental, which means that the prices of these products achieved a lower *P*-value that shows the stationarity.

The other products achieved a lower *P*-value, showing that the null hypothesis was not rejected and that the ADF test confirms that the series are non-stationary and integrated (Lajdová and Bielik 2013).

Table 5 presents maximum likelihood estimates for the GARCH model. This model was widely used in the international literature, mainly to analyse financial and economic time series (Ghahramani and Thavanewaran 2008). It is used to model the dynamic nature of volatility by specifying the conditional mean and variance (Kumar and Moheswaran 2012).

The empirical evidence suggests that there is no serial correlation for the analysed series. The degrees of freedom are 2.97 and 2.88. The conditional *t*-distribution is distinctly fatter tailed than the normal. For butter, skim milk powder, whole milk powder, Cheddar, Edam and Gouda, $\alpha_1 > \beta_1$, which means that the conditional variance depends more on information about volatility observed in the previous period. Only for Emmental and whey powder is the $\alpha_1 < \beta_1$, which suggests that the conditional variance is independent from previous prices.

Table 4. Augmented Dickey-Fuller test (ADF test) results of weekly prices of milk products in the EU

ADF test	*P*-value	
	without trend	with trend
Butter	0.655	0.430
Skim milk powder	0.022	0.080
Whole milk powder	0.005	0.020
Cheddar	0.031	0.085
Edam	0.001	0.053
Gouda	0.009	0.045
Emmental	0.130	0.338
Whey powder	0.217	0.180

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

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Table 5. Generalised autoregressive conditional heteroscedasticity (GARCH) model of dairy products prices in the EU

Variable	α_1				β_1			
	coefficient	SE	z	P-value	coefficient	SE	z	P-value
Butter	0.692	0.062	11.11	0.001	0.399	0.059	6.62	0.003
Skim milk powder	0.919	0.068	13.62	0.003	0.098	0.080	1.22	0.222
Whole milk powder	0.887	0.284	3.12	0.002	0.139	0.298	0.47	0.641
Cheddar	0.738	0.080	9.40	0.005	0.283	0.085	3.32	0.000
Edam	0.992	0.078	12.70	0.006	0.017	0.080	0.21	0.833
Gouda	0.959	0.080	11.97	0.004	0.073	0.075	0.97	0.331
Emmental	0.319	0.036	8.79	0.001	0.711	0.031	22.82	0.002
Whey powder	–0.002	0.038	–0.06	0.950	0.028	0.061	0.45	0.654

α_1 – long-term volatility; β_1 – influence of past volatility on the current volatility; z – standarisation variable; SE – standard error

Source: Own elaboration on the basis of the milk market (Milk Market 2020)

The changes in the milk market in the EU linked to the complete market liberalisation will cause a decline in dairy prices. The stronger competition of the dairy producers and lower costs of production, together with the EU and World Trade Organization policy changes, will cause shorter and deeper cycles in the future (Rosa et al. 2016).

Lessons and implications for milk and dairy products in the EU. The European milk market has been regulated by the CAP. This policy had a huge effect on milk and dairy product prices. In 2015, the quota system was ended, which created disturbances in the market. The purchase prices of farm milk decreased. As a result, many small dairy farmers exited production. Bigger producers that stayed in the market had to be competitive. After the abolition of the quotas, milk and dairy products had to face international competition, mainly from the United States and New Zealand. The CAP instruments reduced milk price changes. Soon, the increasing world demand for milk and dairy products pulled the prices up. To stay competitive in global markets, European producers have to increase production. The average dairy farms in the United States keep 220 cows, whereas EU producers have 22 cows (MacDonald et al. 2020). The production of milk from an average dairy farm in the United States is almost 10 times greater than that of the EU, which affects international competitiveness.

The increasing demand for dairy products such as cheese also affects prices. The best strategy for many dairy enterprises is to process milk and to sell products. Consumer preferences and requirements are also playing a more important role, so milk processing enterprises must adjust to meet consumer preferences. Milk producers and processors must take advantage of the increasing demand in Asian and African countries. To meet the international demand, farmers have invested in milk production, facilities and equipment and must improve their competitiveness in the marketplace (Guth 2017).

Milk and dairy product prices are very vulnerable to economic crises. For example, the financial crisis in 2009 affected the prices of milk and dairy products. At first, the prices fell. Then financial problems also reached the milk producers and dairy processors. The trade participants and processing enterprises did not have money to pay for milk and dairy products, and some of them exited the business.

The COVID-19 pandemic also created temporary problems for the European milk market. In March 2019, the price of milk decreased, and it affected all of the producers with conventions on milk delivery. Export and import have been slower. Raw milk was directed to process into butter and cheese. The demand for milk and dairy products fell, and the stock of milk and dairy products increased. This situation negatively affected processing enterprises, which had to take out additional loans to pay for taxes and other expenditures to keep liquidity ratios. The pandemic affected not only the European dairy industry but also the Chinese and American. The difficulties included an increase in the cost of production, lack of capital for current processing and transport, shortages of workers and difficulties in supply chains (Wang et al. 2020). Global movement restrictions of workers and demand changes were observed. As a consequence of the COVID-19 pandemic, restricted food policy and financial problems were recorded in the sector (Aday and Aday 2020).

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CONCLUSION

The average price of raw milk increased from EUR 32.68/100 kg to 35.87 EUR/100 kg in the years from 2001 to 2019. The 9.8% increase in the price of raw milk was caused by various conditions. The most important were the increase in milk and dairy product consumption in the EU and the development of international trade. The abolition of the quota system in 2015 also affected the price of raw milk and dairy products in the EU.

Looking at their skewness and kurtosis, we can conclude that the analysed time series had positive values in all analysed cases. This finding means that the values of prices of the analysed commodities had tails on the right side of the distributions, which are longer and fatter.

The conditional variance depends more on information about volatility observed in the previous period for butter, skim milk powder, whole milk powder, Cheddar, Edam and Gouda. This finding means that the prices depend on observed tendencies and values in previous periods.

The prices of raw milk and dairy products are co-integrated at the EU level. The direction is visible in both directions. Raw milk prices affect dairy product prices, and dairy product prices affect raw milk prices.

Acknowledgement: The authors of the article thank two anonymous reviewers for their comments which helped to improve it.

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Received: February 8, 2021
Accepted: June 14, 2021