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Content

The price dynamics of selected herbal and animal raw materials

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Abstract

The Federal Republic of Germany is one of the leading producers of milk and milk products as basic elements of the human diet within the European Union. Knowledge of the market prices of milk and milk products and the factors influencing them is important for a number of market operators not only in the Federal Republic of Germany, but also worldwide, when making everyday and major decisions. The aim of this work was to define the development of market prices of selected commodities, namely milk, butter, Gouda cheese, whey, and skimmed milk powder, in the Federal Republic of Germany for the years 2019-2023 and to specify the price correlation between milk and other selected commodities. By analyzing the time evolution using descriptive statistics tools, the development of the market prices of selected commodities was defined, which varied for individual commodities during the period under review. The most stable development was observed for milk market prices, while the most uneven development was identified for butter market prices. The coronavirus pandemic, the war in Ukraine and the high inflation rate had a significant impact on the evolution of prices of selected commodities, with commodity prices rising from their low in 2020 to their high in 2022, but even so, there was no major deviation of prices of selected commodities from their average. The price correlation between milk and other selected commodities was specified using Pearson correlation coefficient and regression analysis. A positive linear relationship was found between market prices of milk and market prices of all other selected commodities. In particular, a very strong linear relationship was registered for the prices of the commodities milk and butter as well as milk and Gouda cheese. During the period under review, the market prices of the selected commodities in the Federal Republic of Germany were influenced by the price of milk 89 % for butter, 81 % for Gouda cheese, 28 % for whey and 49 % for skimmed milk powder. Thus, in addition

to the price of milk, other factors influenced the price of other dairy products, including the size of processors' costs, the volume of production in the period, world market conditions and others.

Keywords: Dairy industry, Federal Republic of Germany, time evolution, price relation, linear regression

Introduction

Milk and dairy products may be included in staple foods consumed by households in Slovakia, as well as in the V4 countries. The inevitability of milk consumption is proven by its positive health effects, above all the prevention of osteoporosis. Currently, the lifestyle of consumers is emphasised, and constant changes positively affect the growing consumption of dairy products. In connection with the situation resulting from the COVID-19 pandemic, consuming milk has been vital as it turned out to have a positive impact on consumers' immunity, which is strengthened by it. The positive effects of milk and dairy products are becoming a precondition for their regular consumption (Kubicová et al., 2021). Headey et al. (2024) also add that dairy products have an extraordinarily rich nutritional profile and have long been promoted to mitigate child malnutrition in high-income countries. Dairy products have a number of nutritional and physical qualities, which make them almost ideal supplemental food for infants, however, they are also nutritionally beneficial even for older children and adults, if they tolerate a certain quantity of lactose.

Milk is one of the most produced, consumed, and protected agricultural commodities in the world (Zolin et al., 2021). The European Union is a huge producer of milk and dairy products. It is also a significant market for their consumption, which is characterised by effective demand and significantly influences the markets of other food products (Klapkiv et al., 2023). In 2022, the EU dairy production reached rounded 160.8 million tonnes, and 10.6 million tonnes of cheese, 2.3 million tonnes of butter and other dairy fats, 55.2 tonnes of whey, and 2.9 million tonnes of skimmed milk powder were produced (Eurostat, 2024). The main producers of milk in the EU are Germany, France, Poland, Italy, and Spain (Klapkiv et al., 2023). The dairy industry is sensitive to seasonal variable factors, such as temperature, cold climatic conditions, and rainfall. They influence the productive and reproductive qualities of dairy animals. Seasonal variability also significantly impacts the quantity of milk consumption and launching milk into the market (Mari et al., 2021).

The conditions of the dairy market both in Czechia and the EU are unstable, especially due to the volatility of milk prices, and they increase pressure on dairy farmers to maximise production with the lowest possible production costs (Syruček et al., 2022). The prices of raw milk are important for the competitiveness of the dairy market and impact the prices of other dairy products and the export (Bórawski et al., 2021). Companies, from small producers to market leaders, are further investing in differentiating their product series

and their production choices are being increasingly oriented to specialities related to sustainability and health benefits. Not only is this trend meeting the needs of consumers, who are increasingly caring for sustainable and healthy food, however, it also has an important impact on the production and profitability of dairy companies (Merlino et al., 2022).

The price volatility of agricultural products is a critical problem for countries with a large agricultural sector. Price changes destabilise the economic market and influence the managerial decisions of producers, mediators, and consumers. The fluctuation of prices is a consequence of factors such as weather, inflation, changes in supply and demand, consumer income, and governmental policy. Prices are also determined by the taste and preferences of consumers. Income prices are significant for market participants in the course of the determination of prices and the assessment of the effectiveness of various types of economic activity. Price research provides detailed and topical information for producers, consumers, and managers. Market institutions can adopt decisions, and scientific institutions can assess the effectiveness of market mechanisms and regulatory instruments on this basis (Rembeza & Seremak-Bulge 2010; Borawski et al., 2020).

This chapter will present other authors' current knowledge, with the help of which data sources and research methods leading to answering the RQ and fulfilling the aim of the work will be sought and considered.

A number of researchers refer to secondary data obtained from various databases to examine the milk market. Roman & Kroupová (2022) obtained information about the monthly prices of fresh milk, butter, Eidam cheese, and dried skimmed milk in the entire country from the CLAL (Italian dairy economic advisory) webpages and from the FAO (Food and Agriculture Organisation of the United Nations). The FAO database, in accordance with Klapkiv et al. (2023), provides appropriate figures for production, consumption, commerce, and prices; the advantage of the Eurostat database is its wide coverage and single data methodology. Syruček et al. (2022) used an available database of the European Commission to determine the average sale prices of dairy products. The database collects the weekly prices of dairy products in the entire EU; they are calculated as the averages of national prices, and the prices of individual countries are not available (Beldycka-Bórawska et al., 2021).

This sub-chapter is further divided into two parts determined by the RQ.

The price development of milk and dairy products

The price development of dairy products in Germany was influenced by a number of factors. The year 2019 was not easy for the dairy industry in Germany, as there was increased evidence about a slowing economy and various political uncertainties appeared; the issue of sustainability especially captured public attention, obviously, the sustainability discourse impacts the dairy industry in several respects (Hunecke et al., 2020). Meyerding & Seidemann (2024) revealed that, although the previous studies determined price as a primary decisive factor, the preferences of German consumers for purchasing milk are especially influenced by the type of cattle breeding and the type of

wrapping material. The coronavirus pandemic changed the total consumption of dairy products in Germany. Although the activity in the dairy market was initially relatively stable and it was primarily influenced by delays in supply chains, the household demands increased, and a significantly higher demand for almost every dairy product was recorded (Mehlhose et al., 2021). In 2021, in accordance with Busch et al. (2022), the volume of milk deliveries decreased, and the prices of dairy products significantly rose, especially at the end of the year, together with the costs for production factors. Nevertheless, the highest quantity of raw milk per farm in the entire EU was recorded in Germany this year, which amounted to 21% of the total quantity within the EU. In 2022 the total economic conditions were significantly changed in Germany in comparison to the previous years, it was the consequence of extraordinary events including pandemic, Russian aggression against Ukraine, and the high degree of inflation, which influenced the development in the dairy market resulting in a sharp rise as well (Langer et al., 2023).

While the aforementioned authors primarily dealt with the causes of price changes, and the general development of dairy market in Germany, Borawski et al. (2020) used the methods of descriptive statistics, involving the calculation of mean, median, minimum, maximum, coefficient of variation, degrees of skewness and kurtosis, for evaluating the changes in the purchasing prices of raw milk in the EU. The same methods were used in the case of measuring the development of butter prices, Edam, gouda, cheddar, dried whey, dried skimmed and whole milk in the EU by Beldycka-Bórawski et al. (2021), who found out that, from 2001 to 2019, the highest average prices were reached by Emmental cheese, and the biggest changes measured by coefficient of variation took place in dried whey (34%), butter (24%), and dried skimmed milk (22%), while smaller changes were observed in dried whole milk (16%), and cheddar (12%). The descriptive method of statistical analysis for describing the development of the dairy sector is also used by Mikelionyte & Eicaite (2023) or Popescu et al. (2020), who determine the average annual growth rate within the methods.

The relation between milk prices and dairy product prices

It is crucial for decision-making in uncertain conditions to understand price interactions that are a pre-condition for understanding the consumer prices of animal products, which is essential for producers, governments, and industrial sectors that are based on livestock farming (Mat et al., 2023).

Statistical instruments called correlation coefficients (CC) measure the strength of the mutual relation between two variables (Sadeghi, 2022). Correlation coefficients quantify the degree and direction of influences in certain characteristics (Mariña, 2021). Correlation is a widespread instrument in statistics to determine how two entities interchange at the same time (Bramante et al., 2020). The tests based on Pearson, Kendall, and Spearman correlation coefficients are usually used during research to find out whether there is a relation between two variables (Karch et al., 2024).

The Karl Pearson's correlation coefficient is one of the most common measurements of linear dependence (Ly et al., 2018). It describes the degree of relation between two

quantitative categorial variables. Variables change in tandem; when one is changed, the other changes in the same direction or takes the opposite direction (Alsaqr, 2021). The correlation between variables is marked by the letter r, and is quantified by a number oscillating between -1 (indicating inverse proportion) and +1 (indicating direct proportion). These numerical values serve as indicators determining the strength of the relation (Sathasivam et al., 2022). Naught represents non-correlation, therefore, there is no dependence between variables (Akoglu, 2018). The Pearson's correlation coefficient may be regarded as a strong indicator if the linear dependency relationship and deviation are normally distributed; if this is not the case, it is recommended to use other dependency indicators such as Kendall's Tau or Spearman's rank correlation coefficient (Bentoumi et al., 2019). Since Pearson's correlation coefficient may be seen as the most frequently used, increased attention should be paid to whether the data are two-dimensionally normal, except the linearity of the relation between variables, and r represents a significant part of Y dispersion, further, the existence of outliers, grouping or limited range of data, appropriate sample size, and whether significant correlation at least indicates causality (Armstrong, 2019). However, it is impossible to interchange the concept of causality with correlation, which is significantly different as it merely concentrates on the connection of trends or formulas (Kathpalia, Nagaraj, 2021). However, Prion & Haerling (2020) note that the stronger the relation between quantities displayed by a correlation coefficient, the better our ability to predict one value from the information about the other one. Furthermore, they point to the appropriateness of using simple linear regression as a 'cousin' of correlation.

The correlation analysis for the mutual relation between milk prices, and dairy products in the EU was used by Beldycka-Bórawska et al. (2021) and revealed that, in most cases, the correlation of prices was positive, the corelation was negative only between butter and Emmental, between butter and dried skimmed milk, and between dried whey and Emmental, which indicates that, as an example, if the price of dried whey rises, the price of Emmental drops, and vice versa.

The regression analysis may be regarded as one of the key analyses that may be used for determining the relation between variables (Attanayake, 2021). In accordance with Etemadi and Khashei (2021), regression modelling is one of the most widespread statistical processes used for estimating relations, and is successfully applied in a wide range of applications. Regression may be divided into three categories: linear, polynomial, and logistic.

Linear regression deals with the relation between a dependent variable and independent variables (Ugwuowo et al., 2023). The name itself reveals that this relation is linear, and is modelled with a linear function (Abu-Faraj et al., 2022; Qiu et al., 2020). Despite linear regression being one of the most important and abundantly used techniques, it is often applied under the assumption that entire information about errors is known, which is impossible in practice (Gong et al., 2019).

Simple linear regression is a statistical technique that is able to estimate the relation between two variables, i.e., between the prediction variable labelled as x and a resulting/response variable labelled as y (Prion & Haerling, 2020). Meijer, Oczkowski, Wansbeek (2021) add that an error in measurement distorts the results of simple linear regression; however, if we know the errors in the absolute or relative form, the adjustment is simple.

Multiple linear regression is a perfect instrument to explain the relation between one dependent variable y and two or more independent variables x1, x2, x3 …, xp, although widely used in practice, it is not recommended in many cases due to its oversimplification of the reality by assuming a linear relation between all independent variables and a dependent variable (Genç & Mendes, 2024). Zhang et al. (2023) point to the issue of selecting explanatory variables x as we will deal with a large quantity of candidates, when many of them have to be purchased, in certain cases, at significant costs.

In connection to dairy industry, linear regression was used, for example, to measure factors influencing the dairy market by the following researchers, Klapkiv et al. (2023), or to reveal the structure of indicators influencing the consumer price of milk by Mat et al. (2023), or to analyse the influence of imported skimmed milk powder and secondary dairy products on the real production price of milk by Espinoza-Arellano et al. (2019), and to identify the relation between factors determining production costs and the prices paid to milk producers by researchers Cristo-Diniz, Neto, & Tavares (2022).

The knowledge of other authors indicates obtaining secondary data with the help of content analysis from public databases for their easy availability and wide coverage to answer both RQ to fulfil the aim of the work. Also, to describe the development of the market prices of milk, butter, Gouda cheese, whey, and dried skimmed milk in the Federal Republic of Germany from 2019 to 2023, which is the subject of RQ1, with the use of the instruments of descriptive statistics, specifically with mean, median, minimal and maximal values, coefficient of variation, and degrees of skewness and kurtosis, for the reason of understanding the qualities of examined data, and their structure. Moreover, to analyse the relation of the market prices of milk and the other aforementioned selected commodities in the Federal republic of Germany from 2019 to 2023, which is the subject of RQ2, with the help of the correlation analysis based on Pearson's correlation coefficient, and with the help of the regression analysis with the use of linear regression, i.e., the most appropriate methods analysing the mutual relation between two variables.

The aim of the work is to define the development of the market prices of selected commodities, specifically milk, butter, Gouda cheese, whey, and dried skimmed milk, in the Federal Republic of Germany from 2019 to 2023, and to specify the mutual price relation between milk and other aforementioned selected commodities.

The following research questions (RQ) are determined in relation to the:

RQ1: How did the market prices of milk, butter, Gouda cheese, whey, and skimmed milk powder develop in the Federal Republic of Germany in the years 2019-2023?

The development of selected market commodities, whose knowledge is indispensable for understanding the interactions of commodity prices, will answer this question. Further, it will provide a wider insight into the market rules of the dairy market in Germany and reveal its seasonal and other oscillations.

RQ2: What was the price relation between milk, butter, Gouda cheese, whey, and skimmed milk powder in the Federal Republic of Germany in the years 2019-2023?

The answer to this question will determine whether milk price impacts the selected dairy products. In the case of price dependence, it will clarify the size of this influence as well.

Methods and Data

The chapter 'data and methods' is divided into two sub-chapters, where data and methods that will be used in the work are introduced.

Data

In this work, secondary data will be used from the web pages of CLAL company (Italian dairy economic advisory, 2024, www.clal.it), providing the average monthly market prices of all selected commodities collected in the Federal Republic of Germany. On the web pages, they are to be found under the card of milk market – instruments – prices. In the case of milk, the gross price of raw milk is from a farm. The prices of butter correspond to a previously formed butter package of up to 250g. The prices of Gouda cheese represent German Gouda cheese containing 45% - 48% fat. Furthermore, only skimmed milk powder and whey powder suitable for human consumption will be counted. For research purposes, the data will be adjusted by converting to the same unit of measurement, €/1000 kg, for each commodity and rounded to 2 decimal places. The adjusted data can be found in Annex No. 1 under the heading: Average monthly market prices of milk, butter, Gouda cheese, whey, and skimmed milk powder in the Federal Republic of Germany from 2019 to 2023.

Methods

As the first one, the time development of the individual monthly market prices of selected commodities (milk, butter, Gouda cheese, milk whey, dried skimmed milk) in the Federal Republic of Germany in 2019 - 2023 will be introduced, and analysed, it will contribute to defining their development, and demonstrate the examined data. The time development of prices will be shown using a line graph. Subsequently, descriptive statistics tools (simple arithmetic mean, median, minimum, maximum, coefficient of variation and measures of skewness and kurtosis) will be used to define the evolution of prices of milk, butter, Gouda cheese, whey and skimmed milk powder in the Federal Republic of Germany for the years 2019-2023 leading to the answer to RQ1. The values will be calculated for each commodity (i.e., for milk, butter, Gouda cheese, whey, skimmed milk powder) separately. The calculations will be performed using MS Excel. The resulting values will be recorded in a table.

It will be followed by correlation analysis based on Pearson's correlation coefficient and regression analysis with the use of simple linear regression. The relationship between the average monthly prices of: 1. milk and butter, 2. milk and Gouda cheese, 3. milk and whey, 4. milk and skimmed milk powder, for the period 2019-2023 in the Federal Republic of Germany will be examined. In the case of correlation analysis, the individual results of the calculation of the Pearson correlation coefficient for each examined pair will be recorded in a summary table. According to the resulting values of the Person coefficient, it will be understood whether the prices are in a certain relationship and whether this relationship is positive or negative. The relationship of the prices of the individual pairs will be examined in more detail using simple linear regression. A linear equation will be defined for each pair, which will then be recorded in a scatter plot. The values of the coefficient of determination will be recorded in a table, and it will be determined how much the price of butter, Gouda cheese, whey, and skimmed milk powder can be explained by the price of milk.

The results of correlation and regression analysis and their interpretation will show whether there is any relationship between the price of milk and the prices of other dairy products and, if so, what kind, which will gradually lead to answering RQ2 and ultimately to fulfilling the objective of the work.

The following methods will be used for calculations:

1) **Simple arithmetic mean** – calculated as the aggregate of all its individual monthly prices for the years 2019-2023 in the specified category and divided by the quantity. The following formula, which is integrated in the MS Excel function under the name *MEAN,* will be used to calculate the simple arithmetic mean.

$$\bar{x} = \frac{x_1 + x_2 + \cdots + x_n}{n} = \frac{\sum_{i=1}^{n} x_i}{n} \quad (1)$$

Where: $\bar{x}$ … the simple arithmetic mean of monthly market prices

$x_1, x_2, \ldots, x_n$ … individual market commodity prices

n … the number of individual monthly market prices equal to the number of months in the monitored period

2) **Median** – the individual monthly market prices for the years 2019-2023 will be organised in an ascending way in the specified category, and the middle element will be determined with the help of the following formula for n even, which is

$$\tilde{x} = \frac{1}{2} \times \left(x_{\left(\frac{n}{2}\right)} + x_{\left(\frac{n}{2}+1\right)} \right) \text{... for } n \text{ even} \quad (2)$$

integrated in the MS Excel function under the name *MEAN.*
Where: $\tilde{x}$ … the median of monthly market prices

$x_1, x_2, \ldots, x_n$ … individual monthly market commodity prices

n … the number of individual monthly market prices is equal to the number of months in the monitored period

3) **Minimal values** – the lowest average monthly price for the years 2019-2023 in the specified category will be determined by the *MIN* function in the MS Excel program.
4) **Maximal values** – the highest average monthly market price for the years 2019-2023 will be determined by the *MAX* function in the MS Excel program.
5) **Variation coefficient** – the degree of relative dispersion will be calculated as the standard deviation ratio of monthly market prices for the years 2019-2023 in the specified category determined by the *SMODCH* MS Excel function, and the absolute values of the earlier calculated simple arithmetic mean. The results of the

$$CV = \frac{\sigma_x}{|\bar{x}|} \times 100 \quad (3)$$

Calculation of the variation coefficient will be given in percentage.
Where: CV … variation coefficient

σ_x … the standard deviation of monthly market prices

$\bar{x}$ … the simple arithmetic mean of monthly market prices

It is valid for the variation coefficient:

CV > 50 % … the set is heterogeneous, the values are scattered further from the centre,

CV < 50 % … the set is homogeneous, the values are close to the average value.

6) **Degree of skewness** – the symmetry of monthly prices in the specified category for the years 2019-2023 around its mean value will be determined with the help of the selection coefficient integrated in the *SKEW* MS Excel function.

$$= \frac{n}{(n-1)\,(n-2)} \times \sum_{i=1}^{n} \left(\frac{x_i - \bar{x}}{\sigma_x}\right)^3 \quad (4)$$

Where: γ … skewness coefficient

x_i… individual monthly market commodity prices

n … the number of the individual monthly market prices equal to the number of months in the monitored period

σ_x … standard deviation of market monthly prices

$\bar{x}$ … the simple arithmetic mean of monthly market prices

It is valid for the skewness coefficient:

$\gamma = 0$ … zero skewness – symmetric distribution,

$\gamma > 0$ … positive skewness – asymmetric distribution, median has a lower value than the mean,

$\gamma < 0$ … negative skewness – asymmetric distribution, median has a higher value than the mean.

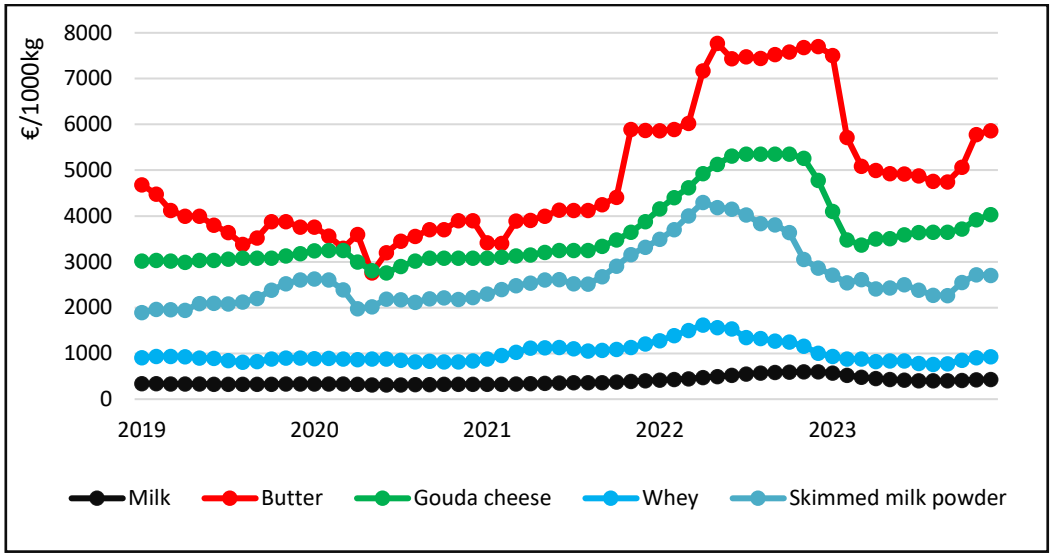
Results

This chapter presents the results of the application of individual selected research methods, on the basis of which the development of market prices of selected commodities, namely milk, butter, Gouda cheese, whey and skimmed milk powder, is defined, and the mutual price relationship between milk and the other selected commodities listed above in the Federal Republic of Germany in 2019–2023 is specified. This chapter is divided according to the specified RQ. The first subchapter presents the time development of individual market monthly prices of the examined commodities in the Federal Republic of Germany for the years 2019–2023, and the results of individual descriptive statistics methods are presented, with the help of which RQ1 will be answered. The second subchapter presents the results of correlation and regression analysis, on the basis of which RQ2 will be answered.

Description statistics methods

Figure 1 shows the time development of the monthly market prices of milk, butter, Gouda cheese, whey, and skimmed milk powder in the Federal Republic of Germany in the years 2019-2023.

Figure 1: The time development of selected commodities in the Federal Republic of Germany in the period 2019-2023.



Source: Authors on the basis of the data (Appendix No.1) retrieved and modified from www.clal.it.

In the table, there are the recorded resulting values obtained by using the individual methods of descriptive statistics, i.e., simple arithmetic mean, median, minimum, maximum, coefficient of variation, and degrees of skewness and kurtosis.

Tab. 1: Statistical characteristics of the monthly prices of examined commodities in the period 2019-2023 in the Federal Republic of Germany.

	Milk	**Butter**	**Gouda cheese**	**Whey**	**Skimmed milk powder**
Simle arit. mean	396,29 €/1000kg	4845,43 €/1000kg	3620,00 €/1000kg	1003,52 €/1000kg	2665,53 €/1000kg
Median	356,60 €/1000kg	4191,00 €/1000kg	3250,00 €/1000kg	903,50 €/1000kg	2519,50 €/1000kg
Minimal value	310,20 €/1000kg	2760,00 €/1000kg	2760,00 €/1000kg	760,00 €/1000kg	1893,00 €/1000kg
Maximal value	600,40 €/1000kg	7770,00 €/1000kg	5350,00 €/1000kg	1623,00 €/1000kg	4299,00 €/1000kg
Coefficient of variation	21,73%	29,55%	21,15%	21,29%	23,91%
Skewness coefficient	1,12	0,87	1,27	1,33	1,20
Kurtosis coefficient	0,07	-0,50	0,34	0,95	0,45

Source: Authors on the basis of the data (Appendix No.1) retrieved and modified from www.clal.it.

The monthly market price of milk developed very evenly compared to other commodities during the monitored period, as can be seen in Figure 1. A certain increase was recorded at the turn of 2022 and 2023, which weakened as 2023 progressed. The average monthly market price of milk during the monitored period was €396.29 per 1,000 kg and was very close to the median price (€356.6 per 1,000 kg), as can be seen from Table 1. Milk was the

cheapest in June 2020, when its price reached €310.20 per 1,000 kg, but the most expensive milk could be purchased in November 2022, when the price climbed to €600.40 per 1,000 kg, almost double. However, prices remained closer to the average price during the monitored period, as the variation coefficient was 21.73%. Nevertheless, it can be stated that during the monitored period an asymmetric price distribution was recorded, both in the form of positive skewness, which means that the average price was higher than the median price (the skewness coefficient took the value of 1.12), and in the form of higher kurtosis, but very close to the normal distribution, when the kurtosis coefficient took the value of 0.07.

The market price of milk developed very evenly during the monitored period in comparison to other commodities, as seen in Figure 1. Certain growth was recorded at the turn of 2022 and 2023, it gradually turned weaker in the course of 2023. The average monthly market price of milk during the period under review was €396.29 per 1,000 kg and was very close to the median price (€356.6 per 1,000 kg), as can be seen from Table 1. Milk was the cheapest in June 2020, when its price reached €310.20 per 1,000 kg, but it was the most expensive in November 2022, when the price climbed to €600.40 per 1,000 kg, almost double. However, prices remained closer to the average price during the period under review, as the coefficient of variation was 21.73%. Nevertheless, it can be stated that during the monitored period an asymmetric price distribution was recorded, both in the form of positive skewness, which means that the average price was higher than the median price (the skewness coefficient took the value of 1.12), and in the form of higher kurtosis, but very close to the normal distribution, when the kurtosis coefficient took the value of 0.07.

Unlike the price of milk, the price of butter developed very unevenly, and there was a marked turn between, which is shown in figure 1, between its growth and drop. From the beginning, the monthly market price of butter fell until the beginning of 2020, when the trend reversed and began to rise significantly. A sharp increase was recorded at the end of 2021 and during 2022. It began to fall again at the beginning of 2023. The decline reversed into growth in November 2023. From Table 1, it can then be seen that the average monthly market price of butter in the monitored period was €4,845.43 per 1,000 kg, and its median was €4,191.00 per 1,000 kg. The monthly market price of butter reached its maximum in May 2022 and its minimum in the same month of 2020. The value of the variation coefficient of 29.55% reveals that the individual prices observed were close to the average price. Asymmetry was noted, both the right-sided skewness of prices and their flatness, as can be seen from the values of the coefficient of skewness (0.87) and kurtosis (-0.50).

It is noticeable from Figure 1 that the market price of Gouda cheese slightly rose till the beginning of 2020, when the trend temporarily changed. Further growth was recorded from the half of the year 2020. The growth was mild at the beginning, it gained pace from the half of the year 2021. In mid-2022, there was a stabilization and then a significant decrease, which stopped only in March 2023. From March 2023, there was a further increase. On average, the monthly market price of Gouda cheese in the monitored period

was €3,620.00 per 1,000 kg and did not deviate too much from the median price (€3,250.00 per 1,000 kg), as recorded in Table 1. The monthly market price reached its bottom in June 2020 (€2,760.00 per 1,000 kg) and was at its peak from June to October 2022 (€5,350.00 per 1,000 kg). It can also be stated that the individual recorded prices did not deviate too much from the average price, when the variation coefficient becomes 21.15%. Prices were slightly asymmetric. A skewness coefficient of 1.27 indicates right-sided asymmetry, and a kurtosis coefficient of 0.34 indicates that the peaks were low and broad.

The monthly market price of whey did not record such oscillations in the monitored period, as displayed in Figure 1. Till the beginning of spring 2021, it oscillated between €810.00 and €953.00 per 1,000 kg, the growth began afterwards. The biggest growth was noticeable in spring 2022, then the price gradually decreased. On average, in the monitored period, we would pay €1,0003.52 per 1,000 kg for whey in the market in the Federal Republic of Germany, which is €100.02 per 1,000 kg less than the median price. The most expensive price would be €1,623.00 per 1,000 kg in April 2022. The cheapest price for whey in the market was in August 2023 (€760.00 per 1,000 kg). Table 1 also shows that the monthly market prices of whey during the monitored period were close to the average price (the coefficient of variation is 21.29%). The average price was higher than the median price, which indicates that there was a right-sided skewness (the coefficient of skewness is 1.33). The peaks formed were then higher and narrower than in the normal distribution (the kurtosis coefficient reached a value of 0.95).

Figure 1 shows that the monthly market price of skimmed milk powder grew from February 2020, then it sharply dropped, and it rose again from April of that year. The growth was gradual at first, then it peaked till April 2022, when there was a turning point, and the market price of skimmed milk powder began to decrease. Their further growth came with the end of the year 2023. Table 1 shows that the average price of €2665.53 per 1,000 kg was close to the median price (€2519.50 per 1,000 kg), and the prices did not depart from the mean too much (VC = 23,91 %), as well as in the case of other commodities. The higher value of the average monthly market price of skimmed milk powder than the median indicates positive skewness (the skewness coefficient is 1.20). The kurtosis coefficient of 0.45 indicates that prices were not symmetrical. The monthly market price of skimmed milk powder reached its minimum (€1,893.00 per 1,000 kg) at the beginning of the observed period and its maximum (€4,299.00 per 1,000 kg) in April 2022.

Correlation and regression analysis

This sub-chapter was divided into two parts in accordance with the individual applied analysis to improve orientation in the results of the correlation and regression analysis, which are presented in this sub-chapter. Within the correlation and regression analysis, the relation between the market prices of these commodity pairs was analysed: 1. Milk and butter, 2. Milk and Gouda cheese, 3. Milk and whey, 4. Milk and skimmed milk powder in the Federal Republic of Germany for the period 2019-2023.

Correlation analysis

In Table 2, the obtained values of the Pearson's (selective) correlation coefficient for each of the examined pairs of commodities were presented.

Tab. 2: The resulting values of the Pearson's correlation coefficient

Variable (x)	Variable (y)	Pearson´s correlation coefficient
Milk	Butter	0,94
Milk	Gouda cheese	0,90
Milk	Whey	0,53
Milk	Skimmed milk powder	0,71

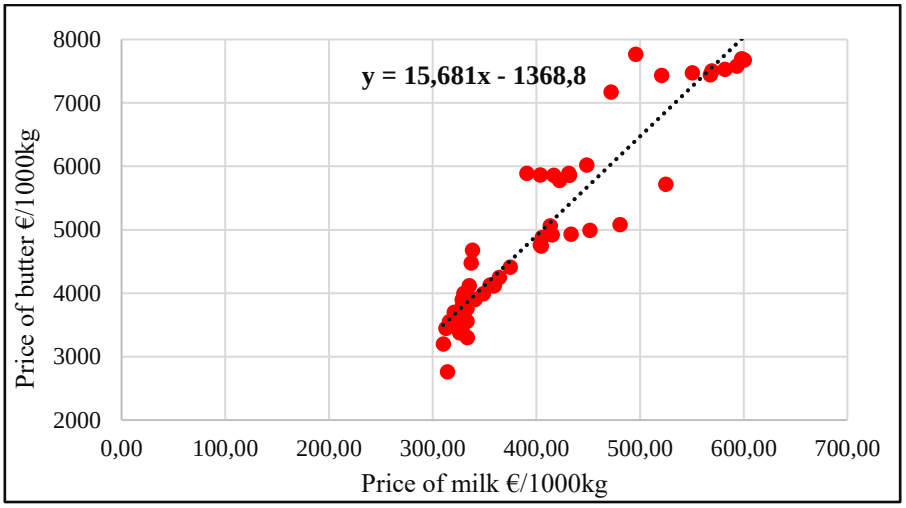
Source: Authors on the basis of the data (Attachment No.1) retrieved and modified from www.clal.it.

It is noticeable in Table 2 that the values of Pearson's correlation coefficient are positive in all the examined pairs of commodities, i.e., there is a relation in each pair of commodity prices, and it is positive. In other words, the positive linear dependence was registered in every pair of commodities in the monitored period, and the increasing price of the first commodity resulted in the increasing price of the other commodity. In the pair of the monthly market prices of milk and butter, the value of the Pearson's correlation coefficient (0.94) gets close to 1, which means a nearly perfect correlation, hence, almost the relation in the form of direct proportion. The high value of Pearson's correlation coefficient in the pair of the monthly market commodity prices of milk and Gouda cheese (0.90) indicates a very strong linear relation. In the pair of the monthly market commodity prices of milk and whey, the correlation was not very strong, but medium, when the Pearson's coefficient acquired the value 0.53. The monthly market prices of milk and skimmed milk powder were in a strong mutual relation. The value of the Pearson's correlation coefficient was 0.71 in this pair.

Regression analysis

The relation between the market price of milk and the market price of butter can be described by the equation y = 15,681x - 1368,8. Figure 2 presents the form of the linear regression line and the strength of the dependence of the market prices of butter on the market prices of milk, which reveals that there is a significant positive relation between the dependent variable and the independent variable.

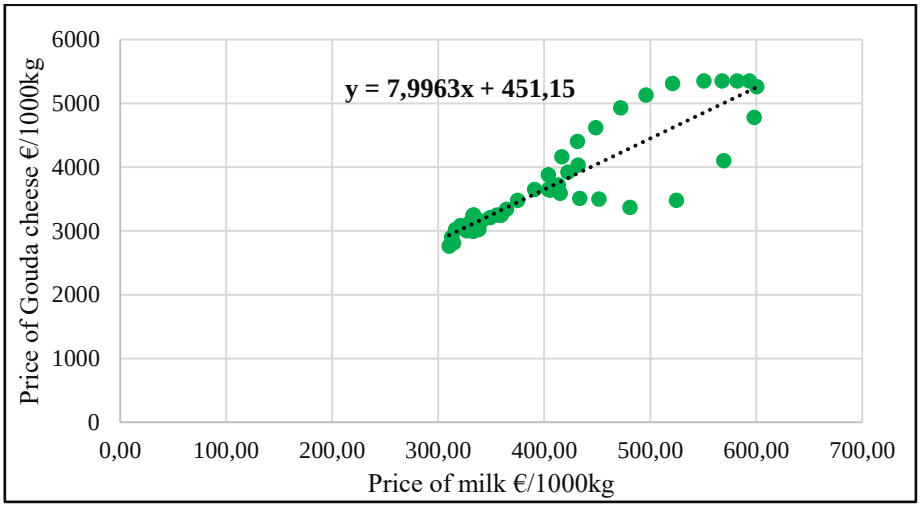
Figure 2: The graph of the regression line – the relation between the market prices of butter and milk



Source: Authors on the basis of the data (Attachment No.1) retrieved and modified from www.clal.it.

Figure 3 makes it noticeable that there existed a significant positive relation between the market price of milk and the market price of Gouda cheese, as the prices of these commodities tended to be on the same line. This relation may be expressed by the equation y = 7,9963x + 451,15.

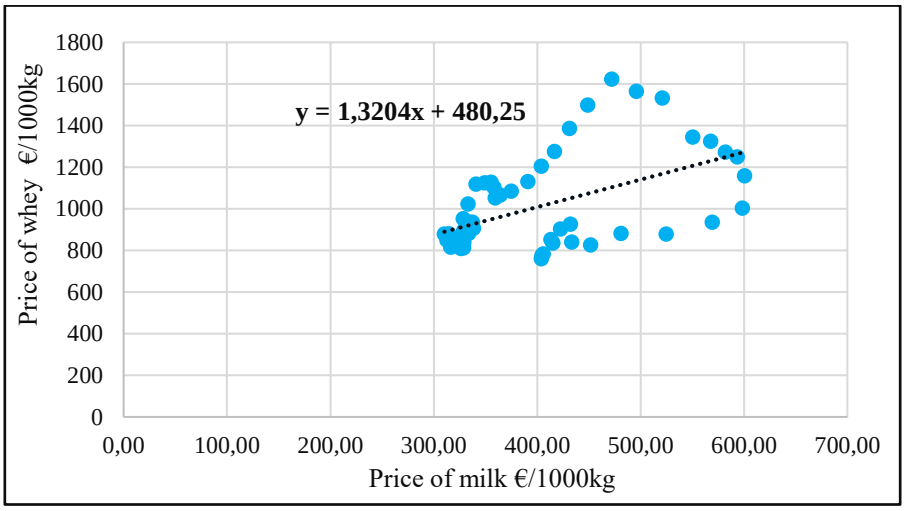
Figure 3: The graph of the regression line – the relation between the market prices of milk and Gouda cheese



Source: Authors on the basis of the data (Attachment No.1) retrieved and modified from www.clal.it.

Medium strength dependence can be noticed between the market prices of milk and whey, as the prices of these commodities had higher dispersion. The mutual relation of these commodities may be presented as y = 1,3204x + 480,25. The form of the regression line was not so steep as a result of the higher proximity of milk prices and whey prices per 1, 000 kg, subsequently shown in Figure 4.

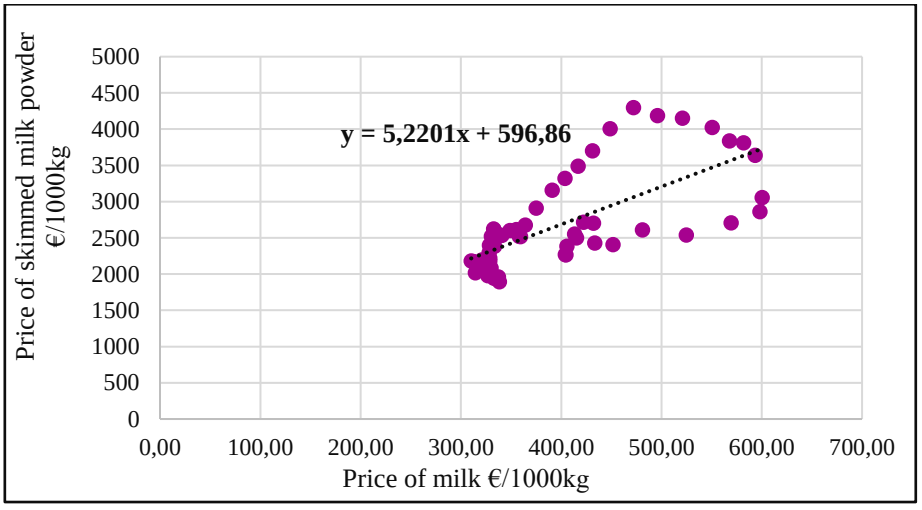
Figure 4: The graph of the regression line – the relation between the market prices of milk and whey



Source: Authors on the basis of the data (Attachment No.1) retrieved and modified from www.clal.it.

It is noticeable from Figure 5 that there was a positive relation between the market price of milk and the market price of skimmed milk powder. These commodities recorded a higher dispersion as well, however, the prices had a linear dependency, and their relation can be represented by the equation y = 5,2201x + 596,86.

Figure 5: The graph of the regression line – the relation between the market prices of milk and skimmed milk powder



Source: Authors on the basis of the data (Attachment No.1) retrieved and modified from www.clal.it.

Table 3 shows the values of the coefficient of determination for each of the examined pairs of commodity prices. All the measured values of the coefficient of determination were

higher than 0, therefore, it may be assumed that the regression analysis served to better understand the relation between the independent variable (price of milk) and the dependent variable (prices of butter, Gouda cheese, whey, and skimmed milk powder).

Tab. 3: The resulting values of the coefficient of determination

Variable (x)	Variable (y)	Coefficient of determination
Milk	Butter	0,89
Milk	Gouda cheese	0,81
Milk	Whey	0,28
Milk	Skimmed milk powder	0,49

Source: Authors on the basis of the data (Attachment No.1) retrieved and modified from www.clal.it.

The value of the determination index (0.89) in the pair of milk, butter came very close to 1, as recorded in Table 3. The market price of butter was under a 89% influence of the market price of milk in the monitored period, and it can be mostly explained with the help of the prices of milk. The market price of Gouda cheese can be explained with an 81% accuracy rate with the help of the market price of milk, as it is shown by the value of the coefficient of determination 0.81. The possible prediction of the price of whey requires other independent variables, as the price of milk is not sufficient. The coefficient of determination acquired the value 0.28, which indicates the mutual linear relation between commodities, however, it is not too big, and the price of whey can be determined with a mere 28% accuracy rate. The price of skimmed milk powder cannot be explained on the basis of the price of milk, even with a 50% accuracy rate. In this case, the regression model determines only 49% of the proportion of the dependent variable, as the coefficient of determination was 0.49.

Discussion

RQ1: How did the market prices of milk, butter, Gouda cheese, whey, and skimmed milk powder develop in the Federal Republic of Germany in the years 2019-2023?

In the course of defining the market prices of selected commodities in the Federal Republic of Germany in the years 2019-2023, the time development of selected monthly market prices was characterised first, and subsequently it was analysed with the help of the instruments of descriptive statistics. The most even development was recorded in the price of milk, however, the market price of butter went through oscillations between growth and decrease in the course of the monitored period. The commodity prices reached their minimum at the beginning of spring 2020, only whey did in autumn 2023, and skimmed milk powder in winter 2019. It is necessary to mention that Covid-19 pandemic hit negatively all sectors of the economy, including the dairy sector (Das, Sivaram and Thejesh, 2021). After the outbreak of the coronavirus pandemic, in accordance with Mehlhose et al. (2021), the total consumption of dairy food changed, although it did not appear at first as the activity had been relatively stable. The pandemic resulted in increasing the input costs of dairy producers, who focused on maintaining the operation of plants, and re-channelling the products from food services to retail, which was connected to processing,

packaging, and distribution (Acosta et al., 2021). The price increase recorded in 2021 can be explained, in accordance with Bushe et al. (2022), by decreasing the volumes of milk and increasing the costs of production factors. The prices of all commodities in the market culminated in the course of 2022, without exception. The sharp increase in prices was observed by Langerem et al. (2023), who add that the cause was the change of general economic conditions in Germany, which had been caused by the coincidence of the corona pandemic, the war in Ukraine, and high inflation. The prices of commodities in the individual months did not move too far from their average prices, which were close to median prices. On average, it was possible to buy the monitored commodities in Germany for: €396.29 for 1, 000 kg (butter), €3, 620.00 for 1, 000 kg (Gouda cheese), €10, 003.52 for 1, 000 kg (whey), and €2, 665.53 for 1, 000 kg (skimmed milk powder). The distribution of commodity prices was slightly asymmetric, with observable right-sided skewness and, except for butter, high kurtosis.

RQ2: What was the price relation between milk, butter, Gouda cheese, whey, and skimmed milk powder in the Federal Republic of Germany in the years 2019-2023?

The price relation of the selected commodities was specified on the basis of the Pearson's correlation coefficient and the regression analysis. The positive linear dependence was registered in every examined pair in the monitored period, which may lead to the conclusion that the prices of other commodities grew with the rise of the milk price. A very strong linear relation between the prices of milk and butter, and between the prices of milk and Gouda cheese, was discovered. A medium dependency was between the prices of milk and whey. A strong, but not very strong, dependency was registered in the prices of milk and skimmed milk powder. The market price of milk influenced the market price of butter at the rate of 89%, Gouda cheese of 81%, whey of 28%, and skimmed milk powder of 49%. The conclusion that the price of milk influences the price of other dairy products was reached by Beldycka-Bórawska et al. (2021) as well, however, they add that the prices of milk are impacted by a wide range of factors, such as the conditions in the world market, the size of the costs of producers, the volume of production in the specific period, food safety measures, etc. The relation between the market prices of milk and other dairy products in the same area over at least an approximate period of time was not examined in more detail by other authors.

Conclusion

Milk and dairy products are essential foodstuffs that offer numerous nutritional and economic benefits. The Federal Republic of Germany is one of the major producers of milk and dairy products within the European Union, which ranks among the world´s leading producers. Fluctuations in dairy product prices affect the profitability of processing companies, influence consumer decision-making, and may even destabilize the economic market. Accurate information on the market prices of milk and dairy products, as well as the factors influencing them, is crucial for stakeholders when making both routine and strategic decisions. The objective of this paper was therefore to define the development of market prices of selected commodities, namely milk, butter, Gouda cheese, whey, and skimmed milk powder, in the Federal Republic of Germany over the period 2019-2023, and to identify the price relation between milk and the aforementioned commodities. This objective was successfully achieved.

The development of market prices for selected commodities was analysed using time series analysis supported by descriptive statistics. The most stable price development throughout the

observed period was observed in milk, whereas butter experienced the most frequent fluctuations between periods of growth and decline. At the beginning of summer 2020, the market prices of most analysed commodities in the Federal Republic of Germany reached their lowest levels. Their subsequent increase was influenced by the COVID-19 pandemic, which had a negative impact on the dairy market by disrupting both supply and demand. A significant escalation in prices occurred in 2022, driven by the combined effect of the ongoing pandemic, the war in Ukraine, and a high inflation rate, all of which contributed to substantial changes in the overall economic environment in Germany. Despite the fluctuations, the market prices of the selected commodities remained close to their mean values, which were close to the median. The distribution of prices was asymmetric, with right-skewed distributions observed for all commodities, and kurtosis for all commodities except butter.

The mutual price relation between the pairs: milk and butter, milk and Gouda cheese, milk and whey, milk and skimmed milk powder was specified with the help of the correlation analysis based on the Pearson's correlation coefficient, and the regression analysis. A positive linear dependence was identified with every examined pair, when a very strong linear relation was registered between the prices of milk and butter, and between the prices of milk and Gouda cheese. The prices of milk and whey were mutually medium-strong dependent, and the relation of the price of milk and skimmed milk powder was linear strong, however, not very strong. The prices of the selected commodities in the market in the Federal Republic of Germany were influenced by the price of milk at the rate of 89% in butter, 81% in Gouda cheese, 28% in whey, and 49% in skimmed milk powder in the course of the monitored period. Apart from the price of milk, the price of other milk products was also impacted by other factors, such as the size of the costs of producers, the production volume in the specific period, the conditions in the world market, etc.

Since it is necessary to base an appropriate decision on adequate information, the knowledge of the market prices of milk and dairy products, their development, and their mutual interaction is necessary for many subjects. The management of enterprises operating in the dairy sector, all their stakeholders, however, also final consumers, and the state, can be such subjects. Furthermore, this work is beneficial for the scientific community as it provides a basis for further research in this area.

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Appendix

Tab 1: The average monthly market prices of milk, butter, Gouda cheese, whey, and skimmed milk powder in the Federal Republic of Germany in the years 2019-2023.

		Milk	Butter	Gouda cheese	Whey	Skimmed milk powder
	01.01.2019	338,30	4680	3020	906	1893
	01.02.2019	337,20	4480	3030	935	1963
	01.03.2019	335,10	4120	3020	936	1958
	01.04.2019	332,90	4000	2990	926	1944
	01.05.2019	329,90	4000	3030	903	2085
	01.06.2019	328,70	3800	3030	894	2094
	01.07.2019	327,10	3640	3060	841	2079
	01.08.2019	326,10	3380	3080	810	2121
	01.09.2019	327,10	3520	3080	826	2203
	01.10.2019	329,20	3880	3080	877	2383
	01.11.2019	330,20	3880	3130	899	2523
2019	01.12.2019	333,10	3760	3180	903	2607
	01.01.2020	332,40	3760	3240	884	2623
	01.02.2020	333,00	3560	3250	894	2603
	01.03.2020	333,50	3300	3250	881	2386
	01.04.2020	326,70	3600	3000	867	1978
	01.05.2020	314,40	2760	2810	880	2020
	01.06.2020	310,20	3200	2760	878	2183
	01.07.2020	312,60	3448	2900	850	2172
	01.08.2020	316,20	3556	3020	816	2119
	01.09.2020	320,80	3700	3080	833	2195
	01.10.2020	326,70	3700	3080	818	2213
	01.11.2020	328,60	3900	3080	813	2180
2020	01.12.2020	328,80	3900	3080	838	2223
	01.01.2021	328,10	3413	3080	878	2298
	01.02.2021	328,20	3401	3100	953	2398
	01.03.2021	333,00	3891	3130	1023	2478
	01.04.2021	340,70	3903	3150	1118	2535
	01.05.2021	348,90	3994	3210	1125	2603
2021	01.06.2021	355,20	4131	3250	1128	2613

	01.07.2021	358,00	4120	3250	1103	2521
	01.08.2021	359,30	4120	3250	1053	2518
	01.09.2021	364,20	4251	3340	1067	2676
	01.10.2021	374,80	4411	3480	1085	2909
	01.11.2021	390,90	5890	3650	1131	3160
	01.12.2021	403,80	5868	3880	1205	3320
	01.01.2022	416,60	5860	4160	1275	3490
	01.02.2022	431,20	5890	4400	1386	3701
	01.03.2022	448,60	6022	4620	1498	4006
	01.04.2022	472,00	7174	4930	1623	4299
	01.05.2022	495,90	7770	5130	1565	4188
	01.06.2022	520,80	7437	5310	1533	4150
	01.07.2022	550,40	7478	5350	1345	4025
	01.08.2022	567,70	7445	5350	1324	3839
	01.09.2022	581,90	7530	5350	1273	3811
	01.10.2022	593,40	7583	5350	1250	3641
	01.11.2022	600,40	7680	5260	1159	3056
2022	01.12.2022	598,10	7700	4780	1003	2863
	01.01.2023	569,30	7504	4100	935	2709
	01.02.2023	524,70	5718	3480	879	2540
	01.03.2023	480,80	5086	3370	882	2610
	01.04.2023	451,50	4995	3500	826	2408
	01.05.2023	433,30	4930	3510	840	2428
	01.06.2023	415,10	4920	3590	835	2500
	01.07.2023	405,70	4880	3640	783	2385
	01.08.2023	403,90	4760	3650	760	2271
	01.09.2023	404,60	4745	3650	776	2265
	01.10.2023	413,20	5064	3720	853	2551
	01.11.2023	422,30	5778	3920	904	2716
2023	01.12.2023	432,00	5860	4030	927	2703

Source: Authors on the basis of the data (Attachment No.1) retrieved and modified from www.clal.it.