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EQUILIBRIUM OF THE DAIRY BUSINESS IN UKRAINE

Due to Ukraine's climatic and geographical features, agriculture makes a relatively significant contribution to the country's gross domestic product compared to other industries. At the end of 2023, this sector accounted for 8.5% of total GDP, ranking fourth after the processing industry, wholesale and retail trade, and public administration [1]. Agriculture, as a complex system, consists of several components. The first involves the cultivation of grain, industrial, fodder, and vegetable crops, as well as fruits, berries, and other types of plant production. The second encompasses livestock production. Unlike other industries, which are less dependent on seasonal factors, agriculture is sensitive to environmental conditions and subject to the laws of nature and seasonality. The influence of these factors can be assessed using various indicators; among them, price is the most responsive in the Ukrainian market economy, as it not only reflects production costs but also indicates shortages, surpluses, or sufficiency of output and responds to changes in population demand. The main principle of a market economy is based on equality among business participants and freedom of competition. This means that both large and small farms or enterprises have equal rights to produce and sell products. The way they balance the market in Ukraine is illustrated in this article using the example of the dairy industry, which maintains deterministic price dynamics over a long period despite exogenous and endogenous influences.

The analysis was conducted using data from official statistical sources, including the website of the State Statistics Service of Ukraine, the World Bank Data portal, FAOSTAT, and others. Specialized Python libraries and tools were applied in this study for econometric modeling, mapping, spatial analysis, and forecasting.

Keywords: economic growth, price fluctuations, seasonality, forecast, data analysis technologies
JEL classification: ***C55, E32, E37, O11, O13***

Завдяки кліматичним та географічним особливостям розташування України, сільське господарство в нашій країні є однією з галузей, внесок якої у валовий внутрішній продукт є досить суттєвим. Зокрема, станом на кінець 2023 року, ця галузь виробляла 8,5% від загального обсягу ВВП та займала 4-те місце після секторів переробної промисловості, оптової і роздрібної торгівлі та державного управління [1]. Дана підсистема економіки займається культивацією зернових, технічних, кормових, овочевих культур, плодів, ягід та інших видів рослинництва. Крім того, розвивається сфера вирощування тварин та виробництва продуктів тваринництва. На відміну від промисловості, яка не залежить від пори року, сільське господарство чутливо реагує на фактори зовнішнього середовища та є підпорядкованим законам природи і сезонності. Простежити вплив цих чинників можна за різними показниками, однак, один з них, а саме, ціна є найбільш еластичним індикатором у ринковій економіці, оскільки є не лише оцінкою вартості закладених у виробництво витрат, а й показником, який відображає дефіцит, надлишок чи достатність обсягу випуску продукції, а також «відгукується» на зміну попиту населення. Варто взяти до уваги той факт, що ринкова економіка базується на рівноправності всіх представників підприємницької діяльності та свободі конкуренції. Це означає, що виготовляти та продавати свою продукцію мають право як великі, так і малі господарства чи підприємства.

Як врівноважують ринок такі господарства в Україні продемонстровано в статті на прикладі молочного бізнесу, який протягом тривалого періоду зберігає детерміновану динаміку цін всупереч внутрішнім та зовнішнім впливам.

Аналіз проведено на основі даних офіційних статистичних джерел, в тому числі, сайту Державної служби статистики України, Data World Bank, FAOSTAT та інших. В роботі використано бібліотеки та інструменти програмного середовища Python для моделювання, просторового аналізу, картографування та прогнозу.

Ключові слова: економічне зростання, коливання цін, сезонність, прогноз, технології аналізу даних

JEL classification: ***C55, E32, E37, O11, O13***

Introduction and review of literature

Analysis of economic systems is carried out using different approaches. The choice of approach is determined by the goal that needs to be achieved in the research process. Problem-solving can answer the questions raised. To solve problems, correctly applied methods are useful tools for unveiling hidden patterns, latent phenomena, or any other peculiarities in the studied subjects or processes. According to one approach, the general system model is initially reconstructed to present its condition as a whole. Then, detailing tasks are performed through the study of individual parts, subsystems, and elements. By the other approach, some subsystems or elements are studied using significant indicators, and then the model is reconstructed as a typical reflection of the whole system's functioning, or as a projection of functionally similar subsystems. The next approach may involve studying individual indicators at an elementary level, with consistent consideration of the relationships between them and the subsequent transition to more complex structures, ultimately leading to the reconstruction of the holistic model of the entire system on their basis. However, to implement any of the approaches, it is necessary to determine which methods should be applied in the study. Sometimes, an information database, its structure and completeness, can suggest which analysis tools should be used to uncover hidden patterns. Several key features of approaches can be clearly identified in contemporary scientific articles of recent years. Researchers study objects of various scales: farms and enterprises, industries, the economy of certain countries, and the world as a whole. Almost all authors concentrate on information and methodological support for investigation and present results of applying a well-founded set of methods to real data. Some of the works focus on studying the impact of endogenous and exogenous factors on the productivity or efficiency of the economic object

Scientific articles often raise issues of stability, resilience, and competitiveness of the economy and individual industries. Forecasts are provided by economists who study the cycles and seasonality of fluctuations in dynamic series of macroeconomic data. Another group of scientists provides evidence of significant threats to food and economic security for countries that act as producers or consumers of agricultural products and may suffer from the devastating consequences of military aggression, natural disasters, economic crises, or pandemics. A leading place is occupied by scientific works dedicated to machine learning for modeling large data sets

A closer look at the key points reveals such tendencies. To gain a deeper understanding of the main trends, it is worth focusing on the approaches applied by scientists from different countries who study the development of agriculture, other industries, and economies in general. Attention was paid to the information and methodological bases of their research and the results obtained. Moreover, studying different investigations helped shed light on various peculiarities of the economic system, including agriculture.

The majority of elaborations focus on the analysis of impact factors on effectiveness and productivity. Generally, regression analysis is the most applicable

approach. Modeling of correlation and regression dependencies is found in some investigations [3, 4, 5], in which price is considered one of the most representative indicators in the economy. As a result of the study, Ukrainian researchers [2] affirm that internal grain prices are formed under the influence of world prices, which can lead to the stability or instability of this product market. Their investigation points out that a decrease in the ability to export products and seasonal price volatility within the country negatively affect producers' profitability, because during the harvest period, sales occur at lower prices than in previous periods; therefore, price fluctuations are negatively related to the stability of producers and the economy.

A similar problem – the influence of increased imports, in particular fruits, berries, and some types of vegetables, on domestic prices and farm profits – has been raised by American authors, who used a utility function to study the elasticity of substitution between domestic and imported products [3]. To predict the potential income of domestic producers under conditions of import growth, researchers examine the total volume of goods supplied by domestic and foreign producers to the country's markets, as well as average producer prices and prices of imported products. It should be noted that a competitive economy does not imply mere price stability (as immutability) or prices held at a fixed level, but rather flexibility in responding to market conditions, meaning the resilience of economic objects to the influence of external destructive factors.

The regression model was also used by researchers in a study based on data from the State Statistics Service of Ukraine website [4]. They examined the impact of lags in milk price changes on fluctuations in dairy product prices. The constructed model helped them predict cost indicators. Simultaneously, it is acknowledged that other factors can influence price formation within the country. In particular, the following issues remain of interest: how prices fluctuated among different categories of producers, and how the price index within the country impacted the potential for export and import of products, as suggested by other investigators.

Another work [5] is dedicated to the dispersion of productivity within farms of all types across 26 European countries. The data set included indicators of production output, as well as weather and soil conditions. To study farm capacity, scientists conducted an analysis using the marginal productivity production function.

The influence of investment policy on the development of dairy farms is analyzed based on information from countries with transition economies, namely Estonia, Hungary, and Slovenia [6]. Using a model of investment equations applied in the study, regression coefficients were obtained as negative for one category of countries and positive for another. It was found that dairy farms use high discount rates in their investments, which leads to an increase in dairy farm sales.

According to the results of the study [7], larger farms have more resources for effective operation. This conclusion was made possible by identifying the relationship between farm size and productivity in Ethiopia.

Information technologies penetrate all spheres of life. Digitalization is a driving factor in qualitative changes across each industry. This is particularly relevant to agriculture, which actively uses geolocation, diagnostics, object recognition, process automation, network technologies, and communication tools. Evidence presented in explorations [8, 9] indicates that digital technologies contribute to the stability and effectiveness of agricultural development. Fast data processing helps support adequate management decisions. According to economists, information technologies may be accessible to large husbandries but exclusive for small farms. This issue can create risks of inequality in their development conditions.

Price, trading power of producers, and other indicators are considered by researchers who study the sustainability, resilience, and competitiveness of economic objects. Economists analyze significant factors that influence the sustainability of agriculture

and producers. As concluded [10], changes in product prices and quota restrictions may lead to the expansion and strengthening of the milk industry.

Emphasis on the capacity of firms, rather than the management system, is made in the investigation [11] based on market structure indicators and strength indicators in the food supply chain. Scientists revealed the consequences of political decisions by the European Union concerning trade practices and dishonesty in commerce. Production functions applied in the exploration of official accounting data helped identify the dominance of small firms in the agricultural sector. At the same time, greater productivity is typically observed in large farms, which is reflected in the volume of trade turnover.

The system approach is the most suitable for understanding macroeconomic fluctuations [12] caused by the accession of countries to the European Union, the introduction of a single currency into circulation, adjustments in consumption levels, and other transformations. This was presented based on the long-term development of five countries that joined the EU. It should be noted that the global financial crisis of 2008 led to disruptions in indicator dynamics, likely related to the evaluation of national currencies and structural shifts in the economies of the countries studied.

Volatility has certain specific features for each economic indicator. For example, price dynamics in France and Germany are characterized by asymmetric fluctuations and sensitivity to external shocks. This means that crisis factors are reflected in rapid changes in world prices. This was demonstrated [13] using vector autoregression applied to milk cost fluctuations.

According to scientists [14], wars, pandemics, and bankruptcies influence industry, agriculture, and even political systems. Innovations, climate change, demographic surges in population, social inequality, and globalization are powerful factors that cause structural shifts. Simultaneously, some factors may drive steady development and quality improvements in industry, while others can destroy not only certain sectors but the economy as a whole.

Generally, works dedicated to the causes and consequences of crises in national economies occupy a prominent place among various studies. Food and economic security provide social and economic stability. As noted [15], most researchers who study the development of complex economic systems, such as agriculture, do not take into consideration many factors that may impact world prices and food security. Scientists have used machine learning tools, such as support vector machines, ridge and linear regression, and decision trees, to extract the most significant factors influencing food security and identified them as determinative in pricing. In this investigation, 104 indicators were grouped according to political, military, economic, and healthcare spheres. The analysis was conducted using data on population involved in power structures, the share of military spending, flows of foreign direct investment and their share in GDP, urban population growth, contributions of agricultural sectors to GDP, product exports, maternal mortality risk, healthcare spending and its share in GDP, and other relevant indicators.

Other researchers [16] assume that risks in agriculture may determine food security both over time and across regions. In other words, the consequences can persist over time and have geographic impacts. Applied autoregression analysis helped reconstruct the distribution and fluctuations of cereal harvests in Italy. The study concluded that regional diversification and productivity play a leading role in ensuring food security.

Methods of regression and cluster analysis are frequently used in studies of agricultural growth stability [17]. Economic security is one of the key factors of competitiveness for farms and the agricultural sector as a whole [18]. This is particularly important for Ukraine and other countries affected by military aggression, for which agriculture is not only one of the main sources of GDP growth but also a critical factor in food security for their own citizens and the world. This fact is confirmed by scientific

researchers [19], who use econometric approaches to investigate the structure and dynamics of Ukraine's agricultural exports. At the same time, the optimization of logistics activities, as economists note [20], plays an important role.

The fluctuations of gross domestic product values, consumer prices, and oil prices remain a focus for economists [21] who address the reconstruction of countries' development indicators. Decomposition of data series into trend, seasonal, and random components can facilitate forecasting and improve accuracy.

To reveal cycles of ups and downs in business activity within economic systems, it is suggested to use harmonic analysis [22]. This approach is universal and can be applied to the study of dynamics in subsystems such as agriculture or other industries.

Typically, all works focus on the information and methodological support for analysis. Emphasis is placed on a critical approach to database formation and careful justification of method selection for study. A significant contribution to understanding patterns of agricultural development in different countries was made by scientists [23] based on the Farm Accountancy Data Network, with farms distinguished by size and type of operation. Adapted stochastic frontier analysis was applied to data covering 4,500 crop farms specializing in cereals and oilseeds across 24 European countries over a 14-year period. The study concluded that the level of data aggregation and the selected characteristics determine the quality of investigation results. Therefore, in their opinion, it may be necessary to modify the approach or adapt the methods.

Considerable attention is paid to methodological aspects by authors [24] who studied labor market data sets in Colombia. The scientists selected an optimal model and made forecasts using machine learning tools, such as component and regression analysis methods, neural networks, support vector machines, and others.

Another methodology was tested in the research [25] to study the impact of investments in the environmental, social, and managerial components of agricultural farms and enterprises. Initially, data sets for 147 European agricultural companies were analyzed using the generalized least squares regression method, which helped to identify the causes of farm profitability. Subsequently, Bayesian network analysis was applied to construct graphs of relationships between significant indicators influencing farm productivity. The database of initial indicators included return on capital and the profitability of companies' securities, which differs from traditional analyses based on changes in gross output or revenue from sales. The applied approach and the identified factors can be proposed when developing strategies for the sustainable development of agriculture.

Contemporary approaches increasingly rely on machine learning algorithms, which help process large data sets related to economic objects and processes. Moreover, these algorithms facilitate model construction, training, validation of adequacy, and obtaining accurate results. All of the works considered allow us to understand the complexity of economic systems and the wide range of characteristics by which we can reconstruct the state of the system, identify the causes of instability, and develop strategies for their mitigation, elimination, or utilization.

The purpose of this article consists of several subgoals. The first is the examination of the main trends in price fluctuations for agricultural products in Ukraine. The second is the study of trends in the Ukrainian dairy sector, whose prices exhibit deterministic dynamics despite the influence of destructive factors. The third is the identification of the causes that determine these trends. Understanding the factors behind fluctuations or sustainability in one sector may help improve processes in other similar sectors.

To achieve this aim, the general dynamics were reconstructed based on fluctuations in average monthly agricultural producer prices for the period 2003–2023. Second, the number of animals and the volume of milk production were studied to shed light on trends in milk productivity over

the years. Third, the peculiarities in output of dairy enterprises and farms were analyzed to determine their role in milk market stability. Finally, a spatial comparison of the contributions of farms and dairy enterprises was presented to visualize their influence across the geographical regions of Ukraine.

Results and discussion. Agriculture in Ukraine is represented by the following sectors: crop production, animal husbandry, fisheries, and forestry. This sector not only supplies industry with resources and raw materials but, most importantly, performs the function of providing the population with essential food products. Products of plant and animal origin contain the necessary nutrients and vitamins that contribute to the growth, restoration, and reproduction of living organisms. Therefore, the industries that produce them are, a priori, expected to always be in demand and profitable. It is known that crop production and animal husbandry, as the main sectors, are affected by seasonal and natural processes, including changes in temperature, the duration of sunny and warm periods, precipitation, and other factors. These factors impact productivity, and the market reacts to them with fluctuations in certain indicators. For example, this is reflected in oscillations in agricultural product prices.

Price is assumed to be the point of agreement at which the producer is willing to sell a product and the buyer is willing to purchase it. At the same time, when there is a shortage of products, the price increases, and when there is a surplus, it decreases. Such shortages and surpluses in agriculture are influenced not only by the producer's capacity but also by the volume of product inventory, which can vary from sufficient levels to rapid reduction due to active consumption. Food stocks are replenished through harvesting during the appropriate seasons of the year, and prices respond flexibly to these changes. This raises several questions: How exactly does seasonality affect price fluctuations for agricultural products? What are the trends in price fluctuations for different types of products? Are there types of products that are not affected by seasonality or random factors?

The producer's price is determined by production costs, the value of fixed assets, working capital, and capital involved in the production process. This is why this indicator was considered among all types of prices. To identify tendencies, the analysis focused on products from the crop and livestock industries, which contribute a significant share to the formation of added value in agriculture. Specifically, producer prices for grains and legumes, sunflowers and other oilseeds, potatoes, vegetables, poultry and livestock, milk and dairy products, and eggs were examined. The most widely used products were studied to understand how price behavior fluctuates under the indirect influence of production, accumulation, and consumption factors within the seasonal cycles that these industry products undergo throughout the year.

The database for analysis included 1,764 values of average prices across seven product categories over 252 months. The analysis was conducted using libraries and tools within the Python programming environment. The study allowed the identification of certain features in the trends of each of the specified products. The impact of seasonality on the prices of these products has been evident over the last twenty years, from 2003 to 2023 (Fig.1).

As seen in the diagrams (Fig. 1), prices oscillate according to certain rhythms of ups and downs, showing a steadily increasing trend over the entire twenty-year period, while also exhibiting annual seasonal regularity. Seasonal changes in vegetable prices are the most pronounced compared to other products. The dynamics of prices for grain and oilseed crops are similar; however, a particularly sharp surge is clearly visible in 2022. It is worth noting that Ukraine achieved its highest grain and oilseed export volumes in 2021, just before the full-scale invasion by the Russian Federation. Since 2022, a significant portion of agricultural lands has been contaminated with explosive objects and substances or placed in combat zones. Moreover, due to attacks on port infrastructure by the aggressor, stored harvests ready for shipment to international

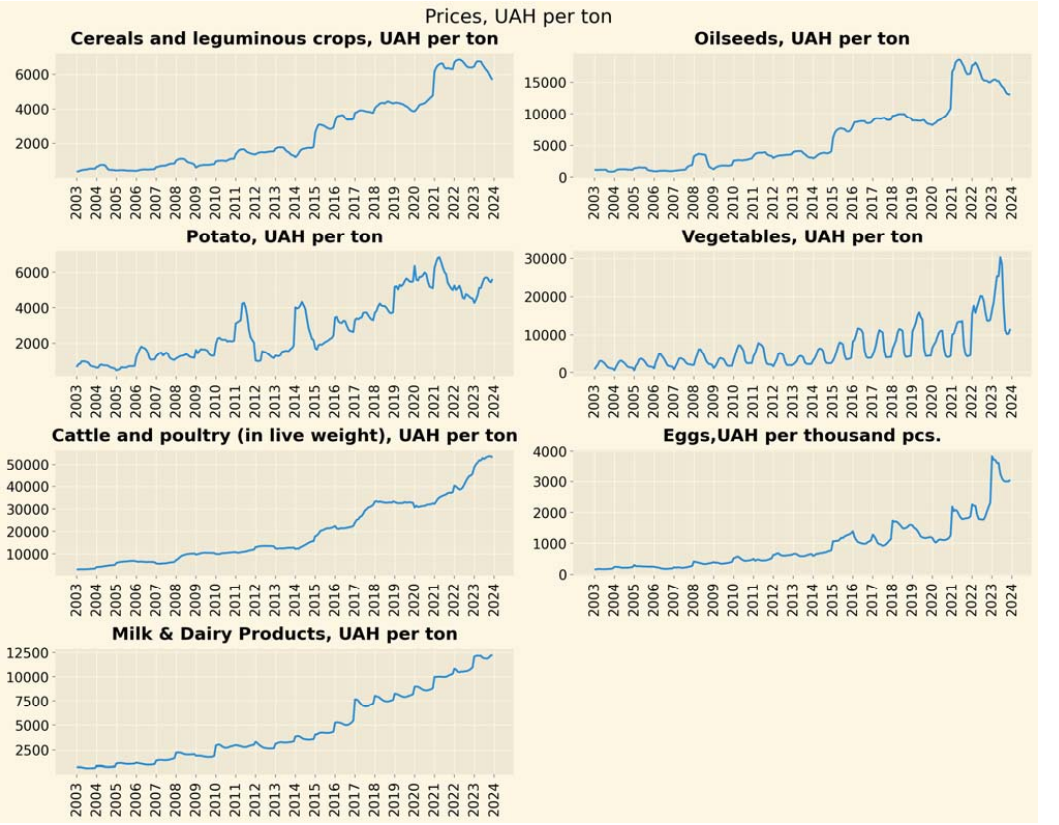


Fig. 1. Fluctuations in producer prices for agricultural products (2003-2023)
Analyzed and compiled by the author based on data [26]

buyers were burned or damaged. The market responded by raising prices for cereals, leguminous crops, and oilseeds. Overall, the war caused an increase in prices for all types of products. Clearly, the armed invasion accelerated inflationary processes in the Ukrainian economy.

Seasonal regularity can be visualized using a heat map. To achieve this, it is reasonable first to normalize the data. The purpose of this method is to bring indicators to a single measurement scale, within which transformed prices change their values within a defined range. The resulting heat map presents colored zones with varying intensities, where zones become lighter as the average producer price increases and darker as it decreases during the corresponding periods of each year (Fig. 2).

The prices of grains, legumes, and oilseeds usually rise in the spring months. This can be explained by the timing of the harvest for these crops. For example, early grains may be harvested in July, while late grains continue to be harvested in October. Consequently, an increase in the harvest volumes of these products motivates producers to reduce prices during the harvest months.

The highest price peak occurs in mid-summer for potatoes and vegetables. This period corresponds to when old stocks have decreased, new crops have not yet been fully harvested, and fresh products of the current year are in high demand as they are just beginning to appear on the markets. The subsequent price decline is associated with the completion of harvesting. Unlike grain crops, some of which can be sown in autumn, vegetables are mostly annuals and are planted in open fields in spring. Moreover, the amplitude of seasonal

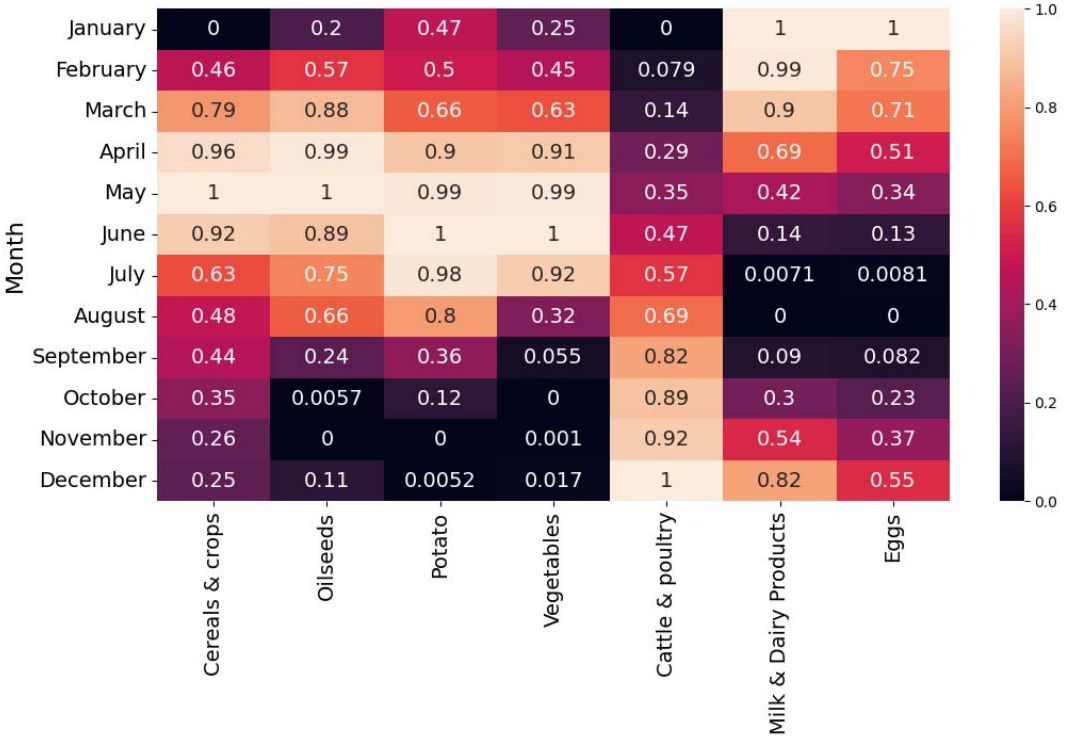


Fig. 2. Heat map of seasonal fluctuations in producer prices for agricultural products (2003-2023)

Analyzed and compiled by the author based on data [26]

changes for grain and oilseed crops is less pronounced than for vegetables.

Cattle and poultry (in live weight), in contrast, become cheaper in the second half of winter and spring. Price fluctuations for these products mainly depend on the growth of population demand for livestock products, particularly meat, which is a more caloric food and especially needed during the cold season. Unconsumed meat stocks require proper storage conditions and spoil quickly, unlike vegetables. Consequently, the market reacts by increasing prices during warmer periods.

Prices for milk and dairy products, almost simultaneously with prices for eggs, fall to their lowest levels at the end of summer. This can be explained by natural changes associated with rising external temperatures, longer daylight hours, increased availability of fresh plant feed, and physiological processes in animals and birds during the warm season, which contribute to increased productivity. In general, prices show the largest amplitude for vegetables and potatoes, and the smallest (with a narrower range) for milk and dairy products. Among all products, milk prices over the past two decades have changed without catastrophic declines or sharp rises, maintaining a stable dynamic.

This tendency raises the question of why prices for milk and dairy products exhibit such predictable determinism. First, examining livestock production data from 1990 to 2023, among many other products, milk production is characterized by an annual decline, which correlates with the decrease in the number of dairy cattle in the country during this period [27, p. 149]. The reconstructed scatter diagram of the correlated series data (Fig. 3) illustrates the trend showing the dependence of milk production on livestock.

Modeling the precise scatter of actual data was not the primary goal of this investigation. The purpose of this diagram

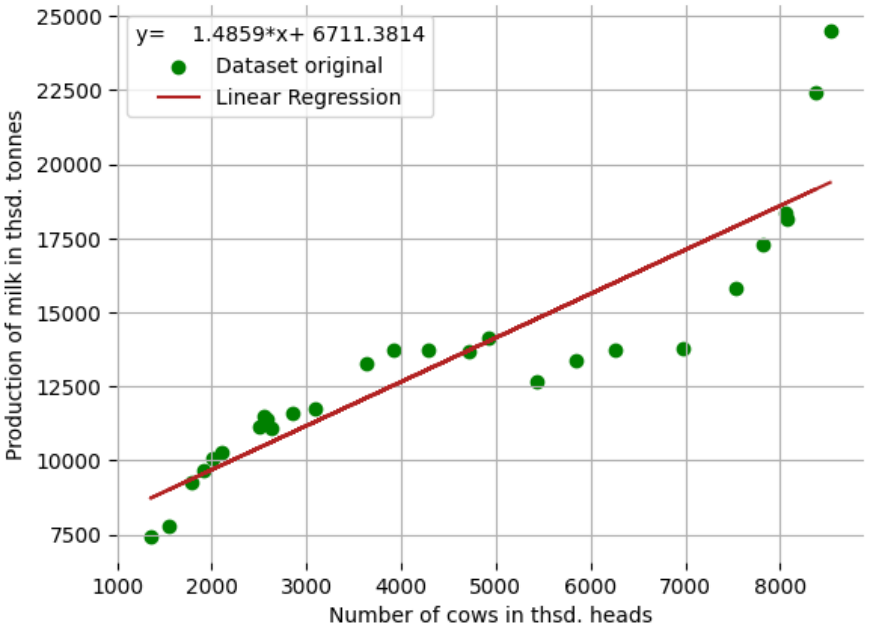


Fig. 3. Trend in cow population and milk volume (1990-2023)
Analyzed and compiled by the author based on data [28]

is to visualize the relationship between livestock numbers and milk production volume. For this reason, it was decided to use a simple linear regression function, although a polynomial function provides a better approximation to the actual data and would be more suitable for forecasting.

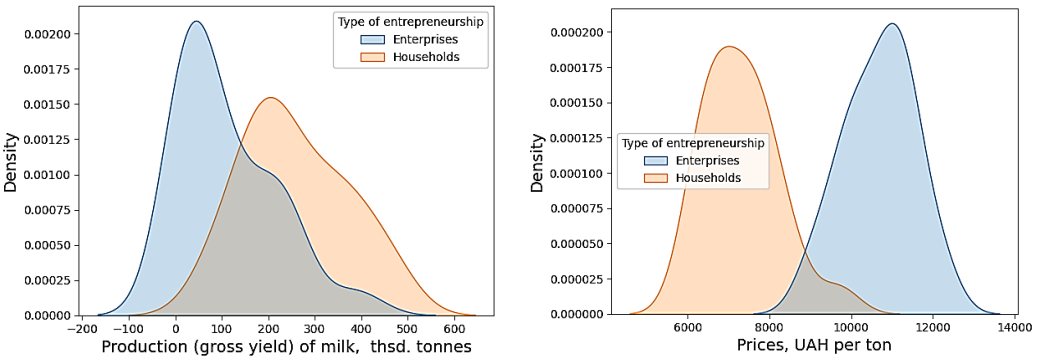
According to official statistics [28], gross milk production in 2023 amounted to 7,430.4 thousand tons, compared to 24,508.3 thousand tons in 1990. The number of cows decreased from 8,527.6 thousand heads in 1990 to 1,352.8 thousand heads in 2023. However, milk productivity increased over the years: in 1990, an average of 2.87 tons of milk could be obtained per cow per year, while in 2023 this figure rose to 5.49 tons. The adoption of modern animal care technologies, high-quality feed, and improved living conditions contributed to this productivity growth. Nevertheless, this did not imply that the profitability of the dairy business was consistently high. On the contrary, according to the State Statistics Service of Ukraine, profitability reached a positive trend without critical declines only from 2012 (2.3%), and by the last recorded date in 2020, the indicator had risen to 20.4% [29].

In Ukraine, both large enterprises and individual households are engaged in the production of milk and dairy products. Which of these is the most efficient? Official statistical sources provide information on production volumes and prices in the regions for both categories of producers. The analysis was conducted using data from the end of 2021 for two reasons. First, the State Statistics Service website provides the most complete data for 2021. Second, as this was the year before the full-scale invasion of the Russian Federation into Ukraine, it allows for a reliable comparison of dairy business efficiency under stable development conditions. In addition, data for 2023 [30] are presented differently. Until 2022, official Ukrainian statistics distinguished only two groups of milk and dairy producers: enterprises and households [31; 32]. In 2023, statistics began to distinguish three categories: enterprises, farms, and households.

A regional analysis for the last year before the full-scale invasion revealed patterns visualized in Figs. 4 and 5. The

distribution diagrams, constructed for both types of businesses based on productivity and producer prices, indicate that as of 2021, households (yellow area on the diagrams) produced more products and sold them at lower prices compared to enterprises (blue area) (Fig. 4).

Examining the constructed scatter diagram (Fig. 5) reveals that an increase in the volume of milk produced by households led to a decrease in the prices they offered on the market, which is less evident for enterprises. In addition, it can be assumed that household activities prevented enterprises



Distribution by production volume (thsd. tons)

Distribution by prices (UAH per ton)

Fig. 4. Distribution diagrams of milk production volumes and producer prices
Analyzed and compiled by the author based on data [31; 32]

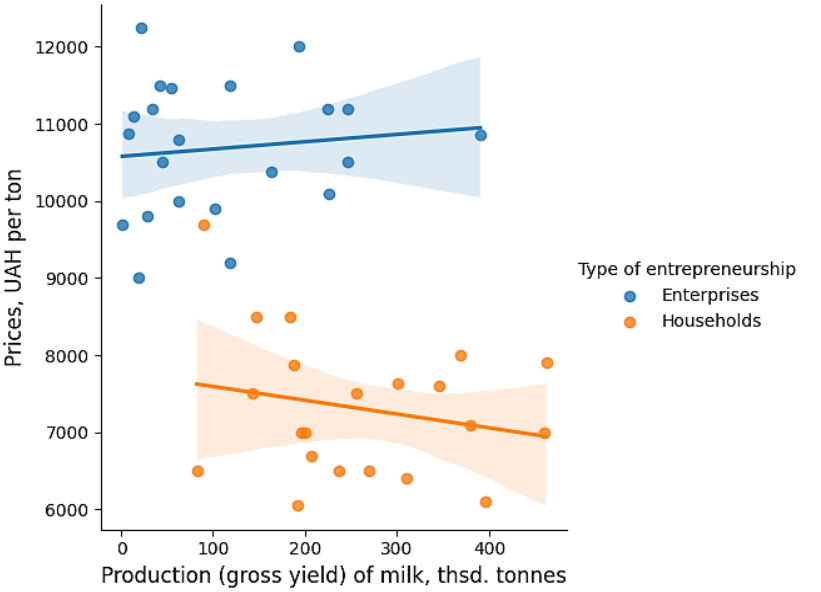


Fig. 5. Correlation between milk production (thsd. tons) and milk prices (UAH per ton) for enterprises and households in 2021 across the regions of Ukraine
Analyzed and constructed by the author based on data [31; 32]

from monopolizing the market and unilaterally dictating prices. Consequently, this competition helped avoid catastrophic fluctuations in producer prices.

To find out in which regions of Ukraine households were the most productive, their shares of total regional productivity were calculated. Based on these values, areas on the map were shaded with colors of different intensities (Fig. 6). Darker colors correspond to a greater contribution of households to regional productivity, while lighter colors indicate a weaker or negligible influence on the dairy market.

The obtained map shows the advantage of household productivity over that of enterprises in the south-central and western regions of Ukraine (areas colored in green and dark green). In particular, the highest contribution of households—over 85%—is observed in Rivne, Lviv, Ivano-Frankivsk, Zakarpattia, Chernivtsi, and Odesa Oblasts. Shares between 66% and 84% are found in Volyn, Zhytomyr, Ternopil, Khmelnytskyi, Vinnytsia, Kirovohrad, Mykolaiv, Dnipropetrovsk, Kherson, Zaporizhia, and Luhansk Oblasts. Other regions (Kyiv, Chernihiv, Sumy, Poltava, Cherkasy, Kharkiv, and Donetsk Oblasts) had a moderate effect on milk market stability from household productivity, with values ranging from 30% to 65%. An exception in the analysis (conditionally marked as 0%) was made for the Autonomous Republic of Crimea, which, as of 2021, was under the control of the occupying administration of the aggressor state, preventing the region from conducting normal economic activity and providing representative statistical reporting. In addition, information from the occupied parts of Donetsk and Luhansk regions was not included in the database, which could affect the accuracy of the indicator calculation.

It is possible that competition between households and enterprises helps balance changes in the milk production sector.

Fig. 6. Map of households' contribution to milk production by region in Ukraine in 2021 year
Analyzed and constructed by the author based on data [31; 32]

Therefore, it is expected that the dynamics of prices for this product will continue a trend of steady growth amid seasonal fluctuations. In particular, price growth is anticipated in 2025. This conclusion is based on a forecast of the dynamics of average sales prices of dairy products in Ukraine for 2003-2024. The forecast was constructed using a Fourier function applied to data for 252 months (Fig. 7).

It is worth examining the dynamics of productivity and profitability by month for enterprises and households separately to compare them, understand the challenges of these types of businesses, and evaluate their advantages and disadvantages. In addition to productivity, it is important to analyze consumer demand and the potential for exporting production abroad. At the same time, specialists note a decline in domestic consumption of dairy products and the accumulation of production surpluses [33]. Moreover, domestic dairy production faces additional risks due to the consequences of the war. By analyzing price volatility, experts suggest mitigating further risks by improving relations between partners in the supply chain, including producers, manufacturers, retailers, and consumers. This could be the next stage of investigation to understand how the chain functions and to identify its weaknesses and strengths.

Conclusions. The analysis was conducted using official statistical data for the period 2003-2023. It included monthly values of producer prices for grains and legumes, sunflowers and other oilseeds, potatoes, vegetables, poultry and livestock, milk and dairy products, and eggs. For each product, months of price increases and decreases were tracked. Different sectors exhibit their own price oscillations, but the most stable and seasonal dynamics are observed for milk and dairy products, which become more expensive in winter and cheaper in summer. Next, trends in the annual number of animals and milk production were constructed for the long-term development of Ukraine. A reduction in the dairy cattle population was noted. Productivity and prices for both enterprises and households were analyzed to determine which are more efficient. Enterprises sell their products at higher prices, while

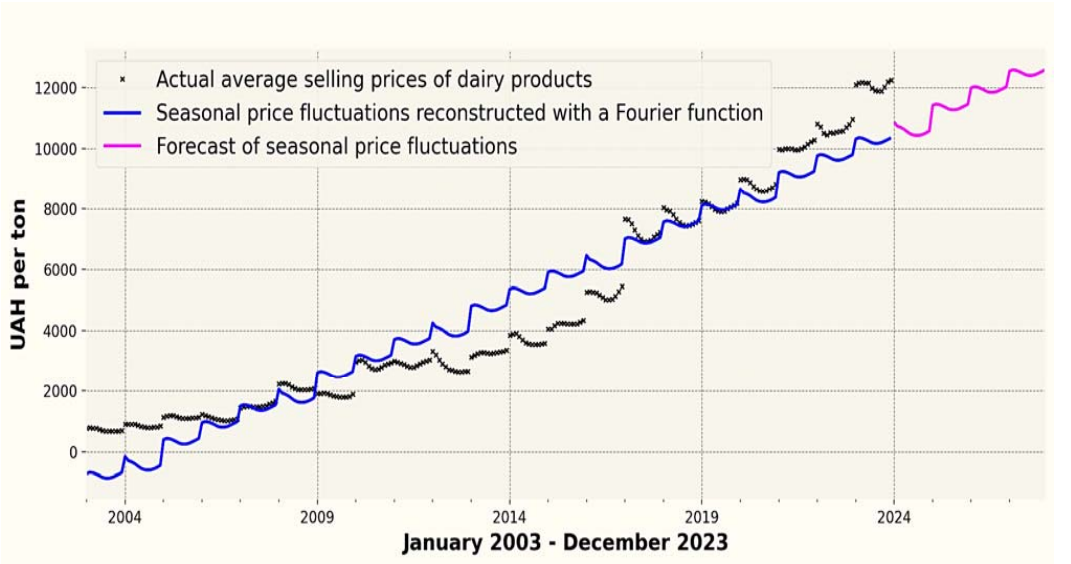


Fig. 7. Forecast of seasonal fluctuations in average sales prices of milk and dairy products using the Fourier function (2003–2024)
Analyzed and constructed by the author based on data [26]

households can supply more milk at lower prices. This competition partially helps establish a balance in the milk and dairy market, protecting it and consumers from catastrophic fluctuations in production volumes and prices. It is also noteworthy that households make a significant contribution to milk production, which varies by region. Finally, an increase in prices is expected in 2025 under similar conditions.

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EQUILIBRIUM OF THE DAIRY BUSINESS IN UKRAINE

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Due to Ukraine's climatic and geographical features, agriculture makes a relatively significant contribution to the country's gross domestic product compared to other industries. At the end of 2023, this sector accounted for 8.5% of total GDP, ranking fourth after the processing industry, wholesale and retail trade, and public administration [1]. Agriculture, as a complex system, consists of several components. The first involves the cultivation of grain, industrial, fodder, and vegetable crops, as well as fruits, berries, and other types of plant production. The second encompasses livestock production. Unlike other industries, which are less dependent on seasonal factors, agriculture is sensitive to environmental conditions and subject to the laws of nature and seasonality. The influence of these factors can be assessed using various indicators; among them, price is the most responsive in the Ukrainian market economy, as it not only reflects production costs but also indicates shortages, surpluses, or sufficiency of output and responds to changes in population demand. The main principle of a market economy is based on equality among business participants and freedom of competition. This means that both large and small farms or enterprises have equal rights to produce and sell products. The way they balance the market in Ukraine is illustrated in this article using the example of the dairy industry, which maintains deterministic price dynamics over a long period despite exogenous and endogenous influences.

The analysis was conducted using data from official statistical sources, including the website of the State Statistics Service of Ukraine, the World Bank Data portal, FAOSTAT, and others. Specialized Python libraries and tools were applied in this study for econometric modeling, mapping, spatial analysis, and forecasting.

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