EVALUATING AND FORECASTING LIVESTOCK PRODUCTION TRENDS IN CROATIA: A SECTORAL ANALYSIS BASED ON ARIMA MODELING

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Abstract: The primary objective of this study was to develop a predictive model for the supply of live livestock in the Republic of Croatia for the period 2024–2029, based on the analysis of historical data. Livestock production has long been a strategically important sector in Croatia, supported by a strong tradition and a notable presence of indigenous breeds. Nevertheless, despite these advantages, the supply of live livestock per production unit has demonstrated persistent negative trends. The study applies the Autoregressive Integrated Moving Average (ARIMA) model to analyze time series data from 2019 to 2023 in order to identify structural patterns and forecast future supply dynamics. Supplementary statistical and econometric methods are employed to examine variation, autocorrelation, and the significance of fluctuations within the series. The analysis also highlights that the cost of production, as a key non-price determinant, plays a decisive role in shaping livestock supply trends. Findings indicate a regressive trend across most livestock sectors, emphasizing the need for targeted policy measures to stabilize and enhance future production.

Key words: Livestock supply, ARIMA model, time series analysis, production forecasting, agricultural economics

Introduction

Land represents the fundamental resource of agricultural production and a key economic asset. Economic goods derive their value from scarcity relative to human needs, meaning they are both desirable and limited in availability. Economics, by definition, concerns the most efficient use of available resources and the realization of optimal decisions in their use. In doing so, it addresses two essential issues: the scarcity of resources and the need for choice (Krugman, 2009).

The problem of scarcity arises from the persistent gap between satisfied and unsatisfied human needs. Although this gap can be reduced through economic progress, it can never be completely eliminated. The scarcity of goods and services that fulfill diverse human needs originates from the limited availability of resources required for their production. Consequently, the treatment of scarce resources and the necessity to choose among their alternative uses establish economics as a science of rational choice, one that seeks to identify and enhance the principles guiding individuals in their economic decision-making (Olson et al., 2009). Making rational economic choices involves comparing benefits and costs, revenues and expenditures, and ultimately striving for a net benefit that justifies the decision.

The selection of a specific type of production is largely influenced by the availability of natural resources and the associated costs (Bašić et al., 2002). Labor, capital, and technology costs determine the most feasible combination of inputs. Through their combination, livestock is raised and produced, and subsequently processed into food and other products that meet consumer needs (Grahovac, 2005). These activities are framed within the concept of economic efficiency, which refers to the production of output units at the lowest possible cost (Bošnjak et al., 2003). The degree of efficiency depends on the prices of production inputs. A key point in understanding economic efficiency is recognizing that it occurs when the cost of producing a given quantity of product is minimized (Arsenović et al., 2002).

In simplified terms, supply refers to the quantity of goods a producer is willing to offer and sell in a specific market, within a given period, and at various price levels. There is a direct relationship between market price and the quantity supplied. When the market price of a good increases, the quantity supplied also increases, assuming other factors remain constant, and vice versa. In the Croatian market, the most commonly raised and marketed livestock species include pigs, cattle, poultry, goats, and sheep. The total supply of a product by all producers in a market at a specific time is referred to as aggregate or market supply. Geometrically, the market supply curve is obtained by horizontally summing the quantities offered by each producer at all alternative price levels.

In addition to price, several other determinants influence supply. Among the most significant are production costs. An increase in input costs leads to higher marginal costs at every level of output, reducing the quantity that producers are willing to supply at a given price (Blanchard, 2005). Conversely, a decrease in costs has the opposite effect, increasing the quantity supplied. Technological progress also contributes to an increase in supply by enabling producers to generate the same output with fewer inputs or greater output with the same input consumption, thereby making them more willing to offer additional products at the same market price.

Other important factors include changes in the prices of related goods. When the price of a substitute product rises, producers may increase the supply of other goods, shifting the supply curve to the right for products whose prices remain unchanged. Government policies also exert a considerable influence on supply. Through fiscal and monetary policy, environmental regulations, product standardization, customs policy, and related measures, the state directly or indirectly shapes the structure and level of production costs (Krueger, 2009). Non-economic factors, such as weather conditions, can also significantly impact agricultural supply. Moreover, the structure of the market and expectations regarding future prices are additional factors influencing supply decisions.

In certain circumstances, a negative relationship may arise between the quantity supplied and the market price of a good. In such cases, the supply curve takes on a negative slope and is referred to as a regressive supply curve. This phenomenon occurs most frequently in agricultural production and is often driven by motivational factors. For example, when the market price of agricultural products increases, producers may maintain the same income level by reducing their output volume, thereby achieving equivalent personal satisfaction with less labor input (Defilippis, 2005). This behavior is especially common among Croatian producers of pigs, cattle, poultry, goats, and sheep, the main livestock categories on the national market.

Based on this theoretical framework, the aim of this paper was to explore the causes of regressive livestock supply, despite the Republic of Croatia possessing comparative advantages in agricultural production relative to its market competitors.

Material and Methods

There are significant regional disparities in livestock production within the Republic of Croatia. Livestock production is closely integrated with crop farming, and the high level of self-sufficiency enables surplus production to be directed toward export markets, making livestock one of the country’s most important export commodities. As the global economy continues to develop, research indicates a growing market demand for cattle, pigs, poultry, goats, and sheep, as well as for processed products derived from these species. In light of favorable market trends, it is essential to systematically improve production capacities and strengthen the overall supply. For the purposes of this research, data were obtained from the Croatian Bureau of Statistics and the Ministry of Agriculture. The data are expressed in absolute numbers (head of livestock).

Table 1. Comparative overview of livestock production volumes from 2019 to 2023

Year	Cattle	Pigs	Goats	Sheep	Chickens
2018	450,727	1,121,032	76,771	636,808	11,412,805
2019	414,125	1,049,123	80,064	636,294	12,746,691
2020	420,239	1,022,350	81,540	657,197	13,056,718
2021	422,881	1,033,048	86,258	661,992	12,096,168
2022	427,587	971,307	85,783	654,339	10,916,570
2023	421,844	944,495	81,581	642,808	10,744,878
Total	**2,557,403**	**6,141,355**	**491,997**	**3,889,438**	**70,973,830**

Source: Compiled by the author based on data from the Croatian Bureau of Statistics and the Ministry of Agriculture of the Republic of Croatia.

According to the data presented in Table 1, variations in the volume of livestock production are evident; however, they do not exceed 15% of the multi-year average. Furthermore, the significant increase in input prices during 2021 and 2022 led to a noticeable decline in production volumes, particularly in the years 2022 and 2023. Among the livestock sectors, the most pronounced reductions were observed in the production of pigs, chickens, and sheep.

For the purpose of modeling the supply of crop products, the ARIMA model was employed. This time series model, specifically the AutoRegressive Integrated Moving Average model, expresses the current value of a time series Y_t as a function of its previous values at time lags t-1, t-2, etc. ARIMA is a structured, multi-stage modeling methodology used for the identification, estimation, and validation of models that combine both autoregressive (AR) and moving average (MA) components (Hillmer et al., 1982), with the aim of achieving the best fit to historical data and producing reliable forecasts. The general form of the ARMA(p,q) model is:

$$y_{t1} = \frac{\mu + \varnothing_1 \cdot y_{t-1} + \varnothing_2 \cdot y_{t-2} + \ldots + \varnothing_p \cdot y_{t-p}}{AR_{(p)}} + \frac{\varepsilon_t - o_1 \cdot \varepsilon_{t-1} - o_2 \cdot \varepsilon_{t-2} - \ldots - o_q \varepsilon_{t-q}}{MA_{(q)}}$$

In this model, μ , $\varnothing_1$, $\varnothing_2$,$\varnothing_p$, represent the model parameters estimated based on sample data (i.e., the time series), while ε_t denotes a random variable

following a white noise process, also referred to as the innovation term. The parameter μ represents the average level of the process, whereas $\emptyset_1$, $\emptyset_2$,$\emptyset_p$ are the parameters associated with lagged variables. Here, p denotes the non-seasonal AR (autoregressive) order, and q denotes the non-seasonal MA (moving average) order.
The ARIMA (p, d, q) model is an extension of the ARMA (p, q) model, where the parameter dd indicates the degree of differencing applied to the time series to achieve stationarity (Fischer et al., 1998). This form is considered standard as it encompasses, in a single expression, the AR(p) model, the MA(q) model, and the ARMA (p, q) model. The ARIMA (p, d, q) model is as follows:

$$\Delta^d y_{t1} = \frac{\emptyset_1 \cdot \Delta^d y_{t-1} + \emptyset_2 \cdot \Delta^d y_{t-2} + \ldots + \emptyset_p \cdot \Delta^d y_{t-p}}{AR_{(p)}} + \frac{\varepsilon_t - o_1 \cdot \varepsilon_{t-1} - o_2 \cdot \varepsilon_{t-2} - \ldots o_q \varepsilon_{t-q}}{MA_{(q)}}$$

Where:

d – Non-seasonal differencing order

In the case where $p = 1$, the model is defined as a first-order autoregressive model, denoted as AR (1). In the AR (1) model, the dependent variable is regressed on its own lagged value (i.e., $Yt{-}1$), indicating that the current value of the dependent variable depends on its own previous (lagged) value and its average level over time.

Autocorrelation was applied as a method for analyzing time series data. It serves to reveal the relationship between the current value of the variable and its previous values. Autocorrelation represents the degree of similarity of a variable across two-time intervals. The results obtained through this method will be used for modelling and forecasting future values in the time series.

Results and Discussion

Figure 1 illustrates the variation in livestock production volumes across different animal production sectors for the period under analysis. The most notable fluctuations are observed in poultry production, followed by pig and cattle production. In contrast, production levels of goats and sheep exhibit relatively minor deviations, indicating a more stable output in these sectors over time.

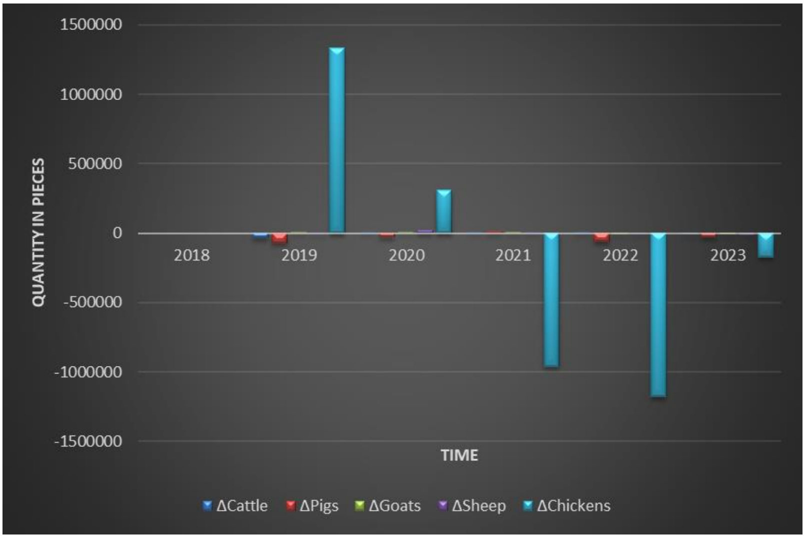

Figure 1. Differences in production volumes by sector

In order to construct the ARIMA model, it is necessary to calculate the standard deviation, variance, mean value, correlation, covariance, and autocorrelation for the analyzed six-year period. The results are presented in Table 2.

Table 2. Comparative overview of statistical results

Species	**n**	**Standard Deviation**	**Variance**	**Mean Value**	**Covariance**	**Significance Level**	**Correlation**	**Autocorrelation**
Cattle	6	816,290,612.8	136,048,435.5	426,238.83	30,104,123.5	0.6715	0.5862	0.1222
Pigs	6	19,227,394,227	3,204,565,704	1,023,559.17	-1,158,948,638	0.8611	0.6206	0.0292
Goats	6	63,919,349.5	10,653,224.92	81,999.50	-1,111,272.17	0.1980	0.1092	0.1464
Sheep	6	60,944,731.3	101,574,552.9	648,239.67	94,280,100.33	0.3249	0.8598	0.4705
Chickens	6	460,189,125.78	766,982,116	11,828,971.67	-475,088,458.41	0.0036	0.6007	0.3641

The mean production volume for cattle is 426,238.83 heads. The standard deviation indicates that the data points show considerable dispersion around the mean value. Variance further confirms that the data set is widely spread around the average. The positive covariance reflects the degree to which the average sum of products deviates from the product of their means. A positive correlation value indicates that an increase in one variable is associated with an increase in the other, and likewise, a decrease in one variable corresponds with a decrease in the other; in other words, the two variables move in the same direction. Similarly, the autocorrelation is positive, confirming consistent dependence within the analyzed series. The significance level demonstrates that the time series interval is reliable.

For pigs, the mean production volume is 1,023,559.17 heads. The standard deviation shows significant variation of data points from the mean range. Variance indicates a wide spread of data around the mean, while covariance is negative, reflecting that the average sum of product deviations is below the product of their means. Despite this, the positive correlation suggests that positive production trends can be expected in the future. The positive autocorrelation indicates that the variables move in tandem, following similar patterns. The significance level suggests that the time series interval is relatively reliable.

In the case of goats, the mean production volume is 81,999.50 heads. The standard deviation reveals significant dispersion around the mean. Variance confirms that the data are spread around the average, while covariance is negative, indicating that the average sum of product deviations is less than the product of their means. The positive correlation shows that the variables increase and decrease simultaneously, moving in the same direction. Autocorrelation is also positive, supporting this interpretation for the analyzed series. The significance level confirms the reliability of the time series interval.

For sheep, the mean production volume is 648,239.67 heads. The standard deviation indicates notable variability in the data points. Variance shows that the data are dispersed around the mean, while positive covariance reflects how much the average sum of products deviates from the product of their means. The positive correlation reveals that the variables tend to move together, increasing or decreasing in parallel. Autocorrelation also has a positive value, indicating consistent behavior in the time series. The significance level suggests that the interval of the time series is reliable.

Regarding chickens, the mean production volume is 11,828,971.67 heads. The standard deviation indicates considerable variability in the data. Variance confirms dispersion around the mean, while covariance is negative, showing that the average sum of product deviations is less than the product of their means. A positive correlation indicates that increases and decreases in the variables coincide, moving synchronously. Similarly, the autocorrelation exhibits a positive value, confirming this pattern within the analyzed series. The significance level indicates that the time series interval is reliable. Based on the statistical results obtained using the ARIMA model, Table 3 presents a six-year forecast of livestock supply.

Table 3. Forecast of livestock supply for the upcoming period

Year	Cattle	Pigs	Goats	Sheep	Chickens
2024	416,101	917,683	77,379	631,277	10,573,186
2025	410,358	920,871	73,177	619,746	10,401,494
2026	404,615	914,059	68,975	608,215	10,229,802
2027	398,872	914,247	64,773	596,684	10,058,110
2028	396,872	818,427	61,382	591,215	9,926,446
2029	393,129	810,435	60,571	585,153	9,886,418
Total	**2,023,075**	**4,320,295**	**344,875**	**3,041,075**	**51,149,010**

The values presented in the table 3 indicate that a decrease in livestock supply is expected across all sectors except for pig farming in the upcoming period. This observation is supported by the statistical results shown in Table 2. Specifically, the supply of pigs is projected to fluctuate, with a slight increase anticipated in 2025 and 2027, while negative trends are expected in the other years. The difference in supply between the analyzed historical period and the projected future period is illustrated in the following Figure 2.

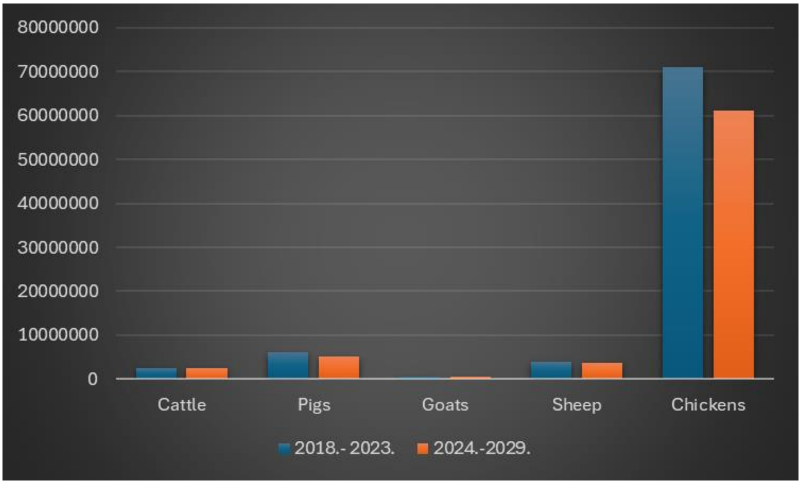

Figure 2. Comparative representation of pig supply trends for the past and future periods

The data presented in Chart 2 demonstrate that the livestock supply during the analyzed historical period exceeds that of the projected future period. A decline in supply is anticipated across all sectors, with average reductions estimated at 5.37% for cattle, 16.32% for pigs, 17.43% for goats, 6.61% for sheep, and 13.94% for chickens. These trends suggest significant shifts in production capacity and market dynamics, which may be influenced by various economic, environmental, and management factors affecting the livestock sector in the forecasted timeframe. Such projections are critical for strategic planning and policy development aimed at sustaining livestock production and meeting future market demands.

Conclusion

The objective of this study was to analyze livestock supply dynamics within the sectors of cattle, pigs, goats, sheep, and poultry over the five-year period from 2018 to 2023 and to project anticipated trends in livestock supply for the subsequent period. The findings indicate that despite the strategic significance of the livestock sector for the Republic of Croatia, forecasts generated using the ARIMA model predict a decline in supply across most sectors in the forthcoming years. Statistical evaluation of the 2018–2023 data series revealed that the standard deviation signifies considerable variability of data points around the mean. Variance analysis further confirmed the dispersion of the dataset around the central tendency, while covariance exhibited a negative average deviation from the mean product values. Notably, correlation and autocorrelation coefficients were predominantly negative in all sectors except for the swine sector, reflecting inverse relationships within the time series data. Autocorrelation analysis corroborated these findings by demonstrating negative deviation patterns for the evaluated series. The significance levels obtained affirm the reliability and robustness of the time series data intervals. Consequently, based on the rigorous statistical assessment and model application, forecasts of future livestock supply were developed, with correlation and autocorrelation measures substantiating the linkage between historical and projected supply values. In summary, the study's aims were met through the systematic application of time series modeling and statistical inference, providing a scientifically grounded forecast of livestock supply trends.

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