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BUILDING PREDICTIVE MODELS OF AGRICULTURAL COMMODITY PRICES BASED ON MACHINE LEARNING METHODS

Abstract:
The agricultural sector is volatile, requiring robust predictive models to forecast commodity prices. This study uses machine learning methods to build predictive models using various algorithms. The research uses historical price data and climatic data to identify patterns influencing market trends. Machine learning models significantly outperform traditional statistical methods, providing actionable insights for farmers, traders, and policymakers. Future research should explore real-time data integration and adaptive models for dynamic market conditions.

Keywords:
Agricultural commodity, price prediction, machine learning, time series analysis.

The agricultural sector plays a pivotal role in the global economy, providing food security and livelihoods for millions of people. However, it faces numerous challenges, including price volatility of agricultural commodities, which can significantly impact farmers, consumers, and policymakers. As global demand for food continues to rise due to population growth and changing dietary preferences, accurate prediction of agricultural commodity prices becomes increasingly crucial. This research paper explores the development of predictive models for agricultural commodity prices using advanced machine learning (ML) techniques, aiming to enhance forecasting accuracy and support better decision-making in agriculture. Agricultural price prediction is essential for various stakeholders, including farmers, traders, government agencies, and consumers. For farmers, accurate price forecasts can inform planting decisions, optimize resource allocation, and enhance profitability. Traders rely on price predictions to make informed buying and selling decisions, while policymakers use this information to formulate strategies that stabilize markets and ensure food security. Furthermore, consumers benefit from stable prices that reflect true market conditions. Therefore, improving the accuracy of agricultural price predictions can lead to more efficient market operations and better economic outcomes for all involved [1].

Despite its importance, predicting agricultural commodity prices is fraught with challenges. The agricultural market is influenced by a myriad of factors, including weather conditions, supply chain dynamics, geopolitical events, and changes in consumer preferences. These factors contribute to the inherent complexity and non-linearity of price movements. Traditional statistical methods such as Autoregressive Integrated Moving Average (ARIMA) have been widely used for time series forecasting; however, they often fall short in capturing the complex relationships within the data [2]. As a result, there is a growing interest in applying machine learning techniques that can handle large datasets and uncover hidden patterns.

Machine learning offers a promising alternative to traditional statistical methods by leveraging algorithms that can learn from data without being explicitly programmed. Recent advancements in machine learning have demonstrated its potential to improve forecasting accuracy across various domains, including finance and healthcare. In agriculture, machine learning models such as Support Vector Regression (SVR), Long Short-Term Memory (LSTM) networks, and Gradient Boosting Machines (GBM) have shown superior performance compared to conventional approaches. These models can capture non-linear relationships and adapt to changing market conditions more effectively [3].

The significance of this research lies in its potential contributions to both academic literature and practical applications in agriculture. By exploring the effectiveness of machine learning techniques in predicting agricultural prices, this study aims to fill existing gaps in research while providing actionable insights for stakeholders in the agricultural sector. Furthermore, the development of an automated prediction system could serve as a valuable tool for farmers and policymakers alike.

The dataset utilized in this research paper is derived from FAOSTAT, specifically focusing on the Russian Federation's producer prices for agricultural goods, measured in USD per tonne [4]. The data spans from 1991 to 2023 and has been filtered to include only relevant entries pertaining to agricultural products as defined by the Decree of the Government of the Russian Federation dated July 25, 2006, No. 458, with amendments up to June 3, 2023. This decree outlines the classification of products into agricultural goods and primary processed products derived from domestically produced agricultural raw materials [5].The primary objective of this research is to develop deep learning models using PyTorch that can accurately forecast prices for various agricultural goods based on historical price data. The selected time frame allows for a comprehensive analysis of trends and fluctuations in agricultural pricing, providing a robust foundation for predictive modeling. By leveraging advanced machine learning techniques, this study aims to enhance the understanding of price dynamics in the agricultural sector, which is crucial for stakeholders involved in production and policy-making.

To illustrate the performance of our machine learning model, in this section we are presenting prediction results of four products: apples, cabbage, cucumbers, and pickles, as well as bone-in fresh or chilled beef. For each of these products, price forecasts were generated and compared to the current prices observed in the dataset.

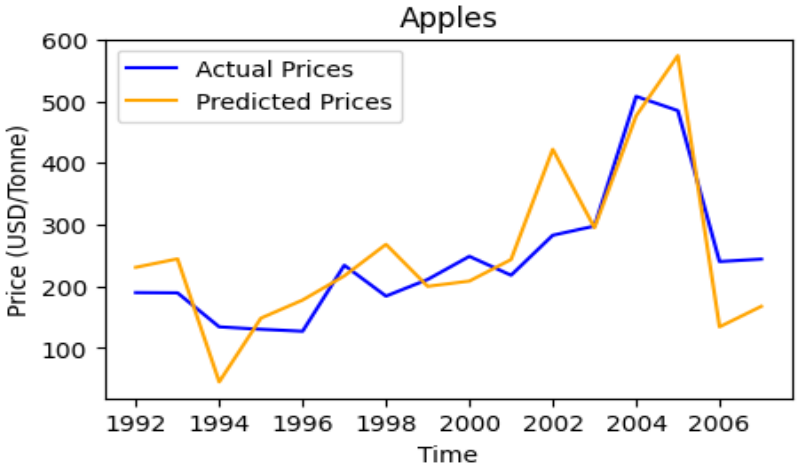

Figure 1 – Apples price comparison between actual prices and predicted prices by the model

The model forecasts indicate a rising trend in apple prices, with peaks during harvest periods. Apple producers can leverage this information to adjust their farming strategies and maximize their profits. By analyzing these trends, they can decide the best time to plant specific apple varieties, optimize their harvest schedules, and sell at the most advantageous prices. Additionally, understanding price fluctuations allows apple farmers to better manage their supply chains and minimize losses. The model's effectiveness in anticipating these changes is crucial for business planning, as it enables producers to remain competitive in a fluctuating market, make informed decisions, and ultimately ensure their sustainability and growth in the apple industry over the long term.

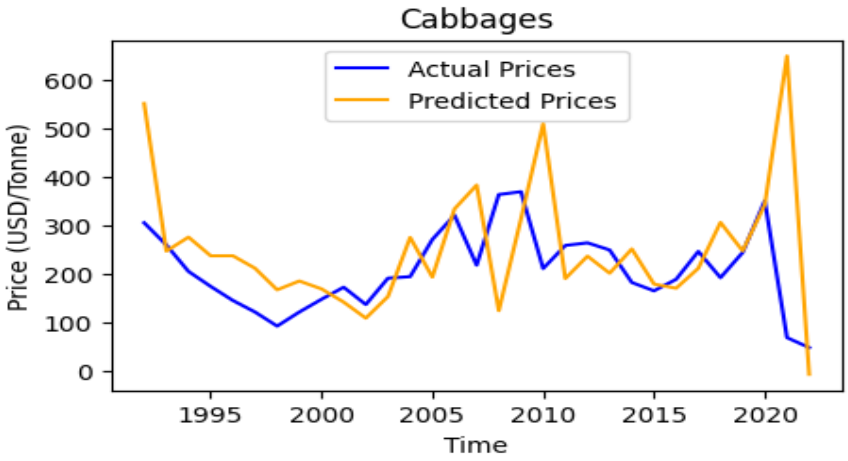

Figure 2 – Cabbages price comparison between actual prices and predicted prices by the model

The model's forecasts for cabbage reveal significant volatility, with increases following major harvests. This volatility can be attributed to various factors such as weather conditions, consumer demand levels, and seasonal fluctuations. By understanding these dynamics, farmers can adjust their farming strategies to harvest at the optimal time, thereby maximizing their profits by selling when prices are highest. Furthermore, this allows them to minimize the financial risk associated with selling during periods when prices are low. Distributors can also better plan their purchases based on these forecasts, enabling them to manage their inventory more effectively and avoid shortages. The informed decision-making facilitated by these beneficial forecasts ultimately benefits the entire supply chain.

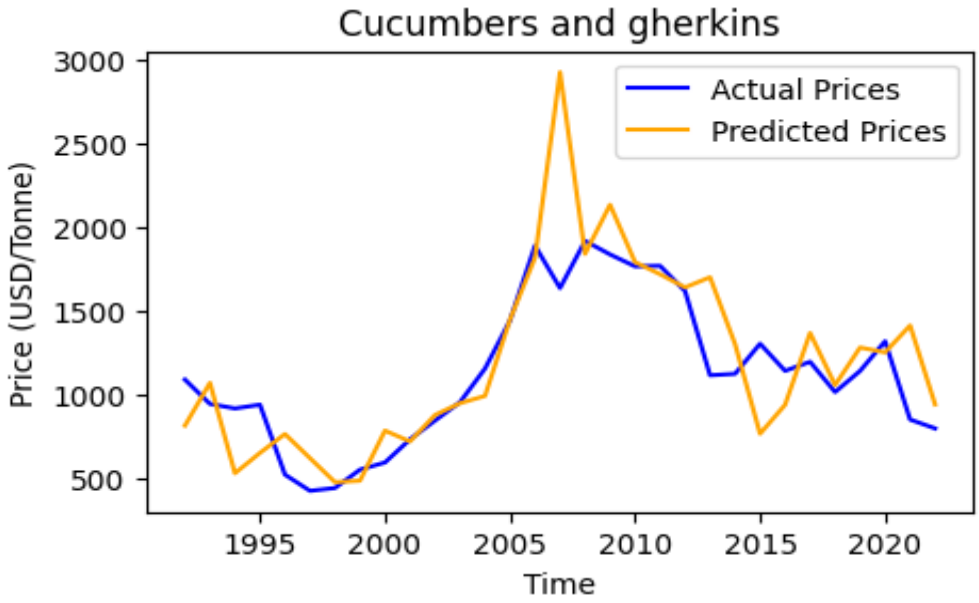

Figure 3 – Cucumbers and gherkins price comparison between actual prices and predicted prices by the model

The model's forecasts for cucumbers and gherkins indicate not only demand peaks in the summer but also consumption trends that vary. By identifying these periods of high demand, producers can adjust their production to maximize their revenues. Fresh cucumbers are popular in salads and cold dishes, while gherkins see increased demand for sandwiches and prepared meals. Additionally, the shelf life of gherkins provides sales opportunities during the winter months when demand for fresh vegetables declines. Producers can thus extend their growing calendar and optimize crop rotation to take advantage of this demand throughout the year. By monitoring market trends and adjusting their production accordingly, they can also prevent surpluses that could lead to price declines. A good alignment between production and demand is crucial for ensuring the profitability and sustainability of farming operations. The model's ability to predict these seasonal fluctuations is essential for maintaining an adequate supply in the market.

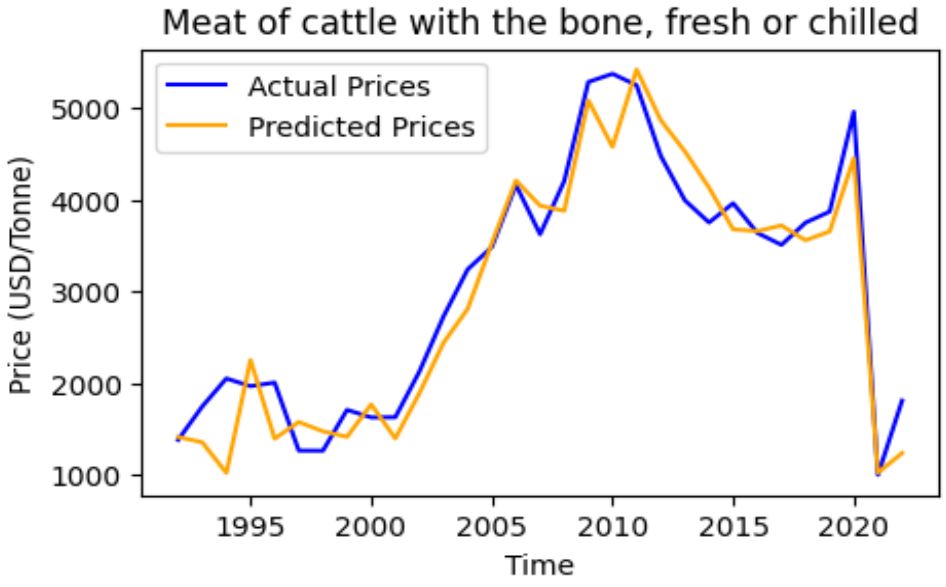

Figure 4 – Meat of cattle with the born, fresh or chilled price comparison between actual prices and predicted prices by the model

For bone-in cattle meat, the model's forecasts indicate a general upward trend with fewer seasonal fluctuations compared to other products. This helps producers secure their long-term profitability and respond quickly to market changes, particularly in the event of a sudden increase in demand or regulatory adjustments.

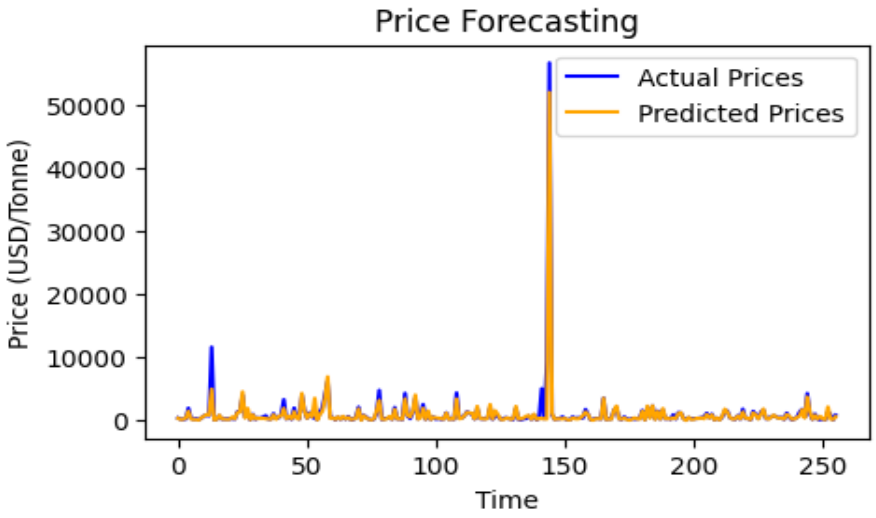

Figure 5 – Overall price comparison between actual prices and predicted prices by the model

The developed model demonstrates a significant ability to predict future prices based on historical data. The forecasts, as shown in the graph above, compared to the current prices observed in the dataset, reveal several key points:

First the forecasts indicate an upward trend for several products, which can be attributed to increasing market demand. The results also highlight the inherent volatility of agricultural markets. Unforeseen events, such as extreme weather conditions or political changes, can significantly influence prices. The comparison between the prices predicted by the model and the current prices shows that while the model is generally accurate, there are discrepancies that can be attributed to external factors not accounted for in the analysis.

This study demonstrates the effectiveness of machine learning models in forecasting agricultural prices in Russia. By integrating advanced deep learning techniques and relying on a robust dataset, these models provide a deep understanding of pricing dynamics that can assist stakeholders in navigating a complex economic environment. The continuous improvement of the model and the integration of new data will be crucial for further refining these forecasts and ensuring their relevance in the face of market changes. This highlights the importance of a data-driven approach to support decision-making in the agricultural sector, thereby contributing to economic stability and long-term profitability.

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