U.S. Meat Production Analysis and Forecasting

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STAT442 Unsupervised Machine Learning

Abstract

This study analyzes U.S. meat production statistics and forecasts future production using machine learning techniques. A Variational Autoencoder (VAE) and a transformer-based forecasting model are employed to capture and predict trends.

Data Source

USDA Domestic Meat Production, Historical.

Analytical Objectives

Correlation Analysis and Time-Series Predictions.

Data Cleaning

Limited the analysis to the period of Jan-2001 to Jan-2025.

Normalized using MinMaxScaler to prevent negative values.

Standardized numeric and datetime formats

Statistical & Machine Learning Procedures

Descriptive Analysis: Correlation heatmap, time-series visualization, and scatter plots.

Predictive Analysis: Variational Autoencoder (VAE) and Transformer-based forecasting.

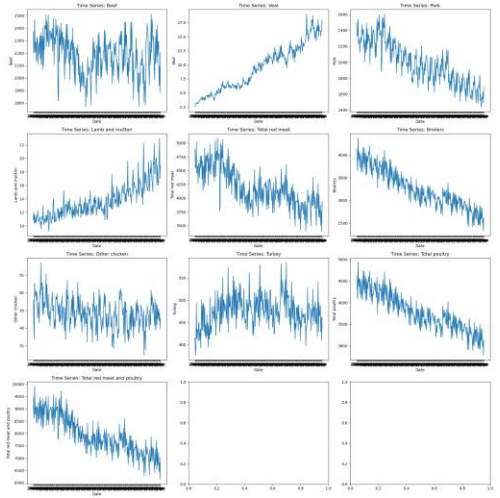
Software & Tools

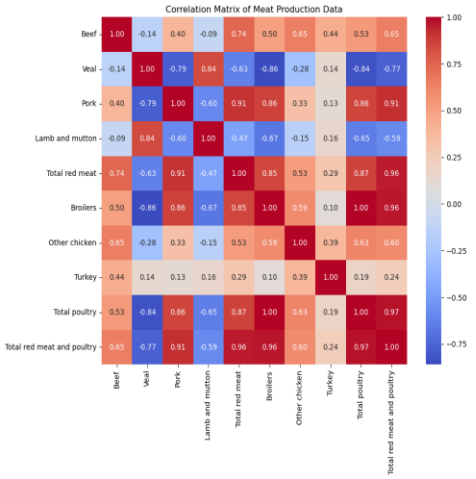
Python (Pandas, NumPy, Seaborn, Matplotlib, Keras, PyTorch).

Model Selection

Captures latent patterns in historical data.

Generates realistic production forecasts using deep learning.





VAE results:

Predicted future trends (original scale):

	Date	Feature_1	Feature_2	Feature_3	Feature_4	Feature_5
0	Jan-25	2069.683594	6.779370	1886.989136	11.834916	4078.976562
1	Feb-25	2178.073975	7.843806	1998.528687	12.213923	4221.109863
2	Mar-25	2213.849854	8.120829	2031.905029	12.247731	4256.477539
3	Apr-25	2226.565186	8.191932	2042.193604	12.242837	4266.317871
4	May-25	2231.521729	8.209249	2045.560181	12.241272	4269.277344
5	Jun-25	2233.714844	8.213400	2046.828735	12.244476	4270.285645

	Feature_6	Feature_7	Feature_8	Feature_9	Feature_10
0	3055.531250	41.515602	457.274445	3639.246826	7594.373535
1	3227.756592	43.829285	466.046814	3851.158691	7978.141602
2	3274.892822	44.600796	465.035797	3914.104736	8079.801270
3	3289.002441	44.902718	463.459747	3933.799561	8104.331543
4	3293.989746	45.041573	462.399292	3940.562988	8108.364258
5	3296.393799	45.115040	461.794006	3943.285156	8107.657715

Transformer results:

Unscaled Future Predictions:

	0	1	2	3	4	5	6	7
0	1741.0094	32.8152	1309.6686	31.1271	2822.1050	1405.9308	380.1586	1956.3875
1	1886.8129	26.1994	1275.5325	24.3964	3365.1445	1713.3722	391.3523	2178.2158
2	1960.1750	21.9284	1373.6909	21.6222	3632.3477	1988.3779	406.1849	2433.3838
3	2003.7330	18.0578	1505.2623	18.4523	3837.4453	2326.9846	429.4685	2763.1968
4	2068.4082	14.1441	1656.1318	16.3812	3932.5452	2686.8577	449.2589	3133.7710
5	2093.5562	10.8822	1793.6283	14.9633	3918.9602	2940.5046	460.7080	3417.1995
6	2113.3562	8.9785	1896.0061	13.3408	3949.0161	3109.6438	468.7467	3625.2012
7	2117.9890	8.1316	1961.2762	12.0100	4004.7803	3216.7402	474.0439	3765.1921
8	2123.5330	7.9407	1994.4252	11.6604	4055.2300	3270.8459	475.9704	3838.4641
9	2125.2400	7.8247	2006.6818	11.5188	4073.0515	3291.5183	475.9724	3863.3645
10	2125.9209	7.7744	2012.1145	11.4549	4081.2314	3300.5908	475.9526	3874.3167
11	2126.2141	7.7519	2014.5176	11.4265	4084.8560	3304.6008	475.9412	3879.1487

Model Architecture

VAE: LSTM Layer with 50% dropout.

Transformer: Three RELU layers, two 10% dropout layers.

Results

Strong correlations observed across all meat categories.

Annual peaks and dips are identifiable.

Forecasting Results

VAE-generated forecasts captured broad trends but lacked precision in monthly fluctuations.

Transformer-based models improved performance by leveraging additional historical data but still lacks accuracy.

Conclusion

Both models are capable of time-series forecasting, but are difficult to train, tune and understand with limited experience.

Transformer-based models offered improvements but require further refinement.

Future research should explore additional tuning and alternative deep-learning approaches.

References

Heidenreich, H. (2024, March 3). Modern Pytorch techniques for Vaes: A comprehensive tutorial. Hunter Heidenreich, Machine Learning Engineer. https://hunterheidenreich.com/posts/modern-variational-autoencoder-in-pytorch/

Su, L., Zuo, X., Li, R. et al. A systematic review for transformer-based long-term series forecasting. Artif Intell Rev 58, 80 (2025). https://doi.org/10.1007/s10462-024-11044-2