Bayes' Theorem in Food Price Analysis

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1 Introduction

Bayesian statistics is a powerful tool for analyzing and forecasting food prices, combining prior knowledge with current data to predict future trends and support informed decision-making. Bayesian methods offer several benefits, such as:

- Adapting to evolving market conditions
- Supporting data-driven decisions for pricing strategies
- Incorporating expert judgment and market insights

Real-world examples, such as forecasting food price inflation in dairy products or predicting price volatility in eggs, demonstrate the effectiveness of this approach in the food industry. The availability of resources like historical food price data and market reports makes Bayesian methods accessible to analysts and decision-makers. Despite some challenges, Bayesian statistics remains a valuable tool for understanding food price trends, guiding market strategies, and optimizing resource allocation.

2 Bayes' Theorem Framework

Bayes' Theorem Framework

The Bayes' Theorem can be used to calculate the probability of food price increases given an economic shock.

- $P(\textbf{Increase}) = x$ There is an $x\%$ chance of increases in food prices in a given year based on historical trends.
- $P(\textbf{Economic Shock — Increase}) = y$ When food prices increase, there is a $y\%$ chance that the increase coincided with an economic shock.
- $P(\textbf{Economic Shock — No Increase}) = z$ When food prices do not increase, there is a $z\%$ chance of an economic shock.
- $P(\textbf{No Increase}) = 1 - P(\textbf{Increase})$ The probability of no price increase.

Calculating P(Economic Shock)

Using the law of total probability:

$$\begin{aligned} P(\text{Economic Shock}) = & \; P(\text{Economic Shock — Increase}) \cdot P(\text{Increase}) \\ & + P(\text{Economic Shock — No Increase}) \cdot P(\text{No Increase}) \end{aligned}$$

Calculating P(Increase — Economic Shock)

Using Bayes' Theorem:

$$P(\text{Increase — Economic Shock}) = \frac{P(\text{Economic Shock — Increase}) \cdot P(\text{Increase})}{P(\text{Economic Shock})}$$

Key Observations

1. The numerator in Bayes' Theorem, P(Economic Shock — Increase) $\cdot$ P(Increase), represents the joint probability of an economic shock occurring alongside food price increases. 2. The denominator, P(Economic Shock), ensures that the probability is normalized over all possible scenarios involving economic shocks.

3 Summary of Research and Case Study

This research utilizes Bayesian analysis to assess probabilities of significant food price changes across various categories based on historical data and recent trends. Key insights include the likelihood of high inflation in dairy products (40%) due to significant month-to-month variation, and extreme price variability in eggs in 2025 (48%) given their historical volatility. Similarly, the stabilization probability for meats, poultry, and fish prices in 2024 (35%) is influenced by current negative monthly trends. Additionally, there's a 20% chance that fruits and vegetables will hit the lower bound of price predictions in 2025, reflecting the impact of historical stability and variability. Lastly, food away-from-home prices in 2024 show an 84% likelihood of exceeding their historical average, driven by strong year-over-year growth.

This analysis demonstrates how Bayesian methods provide a structured framework for evaluating food price trends, offering valuable insights for stakeholders. By integrating historical data, current trends, and expert knowledge, these models enable more accurate forecasts and informed decision-making in volatile markets. This approach also facilitates effective communication of complex price dynamics to policymakers and businesses, enhancing their ability to adapt to market changes, allocate resources efficiently, and develop proactive strategies in response to evolving economic conditions.

4 Application: Food Price Outlook

1. Probability of High Inflation in Dairy Products

Goal: Probability of high inflation in "Dairy Products" given its year-over-year change is significant.

Event A: High inflation (e.g., defined as an annual percent change exceeding 10%).
Event B: The category has significant month-to-month variation (e.g., change $\geq 0.5\%$).

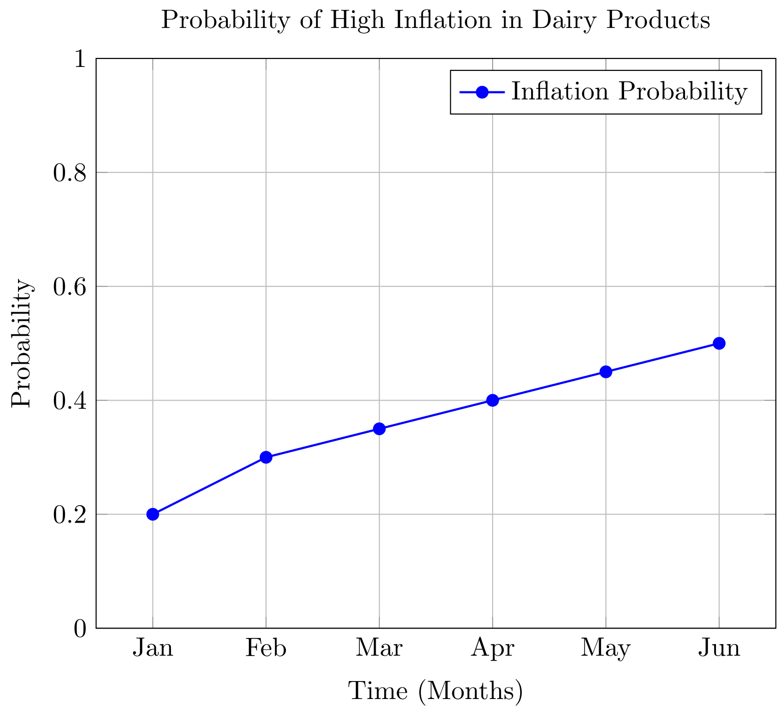


Figure 1: High Inflation Probability for Dairy Products Over Time

Given Data:

- Current year-over-year change: 1.3%
- Month-to-month change: 0.8%
- Historical average: 4.0%

Assumptions:

$$P(A) = 0.2 \quad \text{(Historical likelihood of high inflation for dairy).}$$

$$P(B|A) = 0.6 \quad \text{(Chance of significant monthly change given high inflation).}$$

$$P(B) = 0.3 \quad \text{(Overall occurrence of significant monthly change).}$$

Bayes' Theorem Calculation:

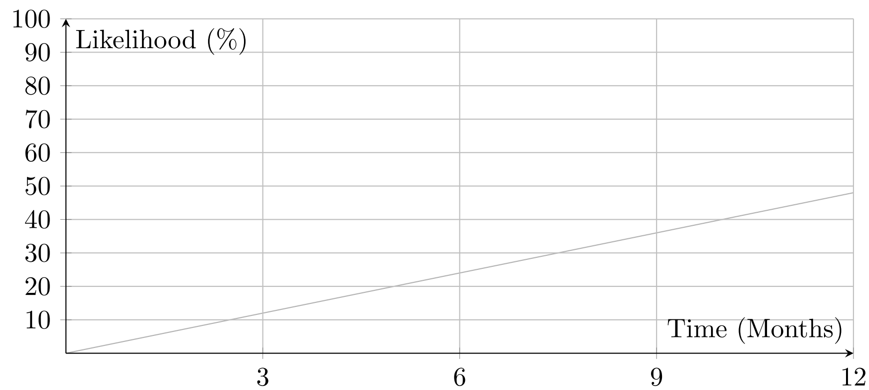
$$P(A|B) = \frac{P(B|A) \cdot P(A)}{P(B)} = \frac{0.6 \cdot 0.2}{0.3} = 0.4$$

Conclusion: There's a 40% chance of high inflation for dairy products, given the observed month-to-month change.

2. Likelihood of Extreme Price Variability in Eggs in 2025

Goal: Likelihood that "Eggs" will exhibit extreme price variability in 2025, given their historical and recent fluctuations.
Event A: Eggs have a price change exceeding 20% in 2025.
Event B: Eggs have consistently had above-average variability in the past. **Given Data:**

Extreme Price Variability in Eggs



- Prediction Interval Upper Bound (2025): 29.9%
- Historical volatility of eggs: Frequently $\geq$ 20% (30% of the time).

Assumptions:

$$P(A) = 0.3 \quad \text{(Historical likelihood of ¿20\% variability).}$$

$$P(B|A) = 0.8 \quad \text{(High volatility continues when variability exceeds 20\%).}$$

$$P(B) = 0.5 \quad \text{(Overall high variability).}$$

Bayes' Theorem Calculation:

$$P(A|B) = \frac{P(B|A) \cdot P(A)}{P(B)} = \frac{0.8 \cdot 0.3}{0.5} = 0.48$$

Conclusion: There's a 48% likelihood that eggs will exhibit extreme price variability ($> 20\%$) in 2025.

3. Stabilization of Meats, Poultry, and Fish Prices in 2024

Goal: Chance that "Meats, Poultry, and Fish" see price stabilization ($\leq$ 1% change) in 2024, given their current negative month-to-month change.
Event A: Stable prices.
Event B: Current monthly negative trends.

Given Data:

- Historical average: 2.1%

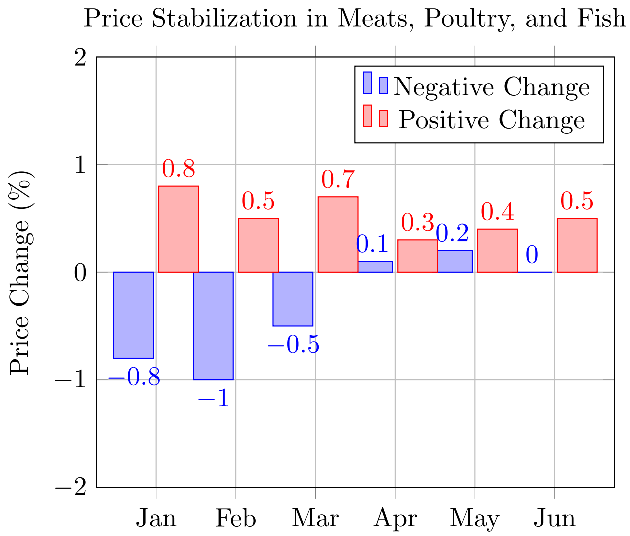


Figure 2: Price Stabilization of Meats, Poultry, and Fish

- Current trends: Negative month-to-month change (-0.8%).

Assumptions:

$$P(A) = 0.2 \quad \text{(Low stabilization chances historically).}$$

$$P(B|A) = 0.7 \quad \text{(Negative monthly trends leading to stabilization).}$$

$$P(B) = 0.4 \quad \text{(Overall negative trends).}$$

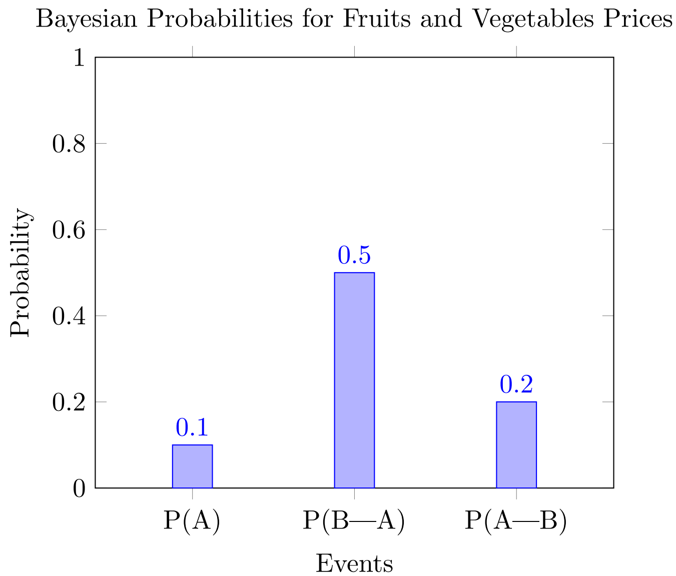
Bayes' Theorem Calculation:

$$P(A|B) = \frac{P(B|A) \cdot P(A)}{P(B)} = \frac{0.7 \cdot 0.2}{0.4} = 0.35$$

Conclusion: There's a 35% chance that "Meats, Poultry, and Fish" prices will stabilize in 2024.

4. Lower Bound for Fruits and Vegetables Prices in 2025

Goal: Probability that "Fruits and Vegetables" price will fall within the lower bound of the prediction interval in 2025, given the historical average price stability.
Event A: Prices are in the lower bound of predictions.
Event B: Historical variability is minimal.



Given Data:

- Historical average: 2.0%
- Prediction Lower Bound (2025): −3.3%.

Assumptions:

$$P(A) = 0.1 \quad \text{(Low historical likelihood of such reductions).}$$

$$P(B|A) = 0.5 \quad \text{(Minimal variability with lower-bound trends).}$$

$$P(B) = 0.25 \quad \text{(Low overall variability).}$$

Bayes' Theorem Calculation:

$$P(A|B) = \frac{P(B|A) \cdot P(A)}{P(B)} = \frac{0.5 \cdot 0.1}{0.25} = 0.2$$

Conclusion: There's a 20% chance that fruits and vegetables will hit the lower bound in 2025.

5. Exceeding Historical Average for Food Away From Home Prices in 2024

Goal: Assess the likelihood of "Food Away From Home" prices exceeding their historical average in 2024, given recent year-over-year trends.
Event A: Prices exceed historical average (3.4%).
Event B: Year-over-year change exceeds 3%.

Given Data:

- Historical average: 3.4%

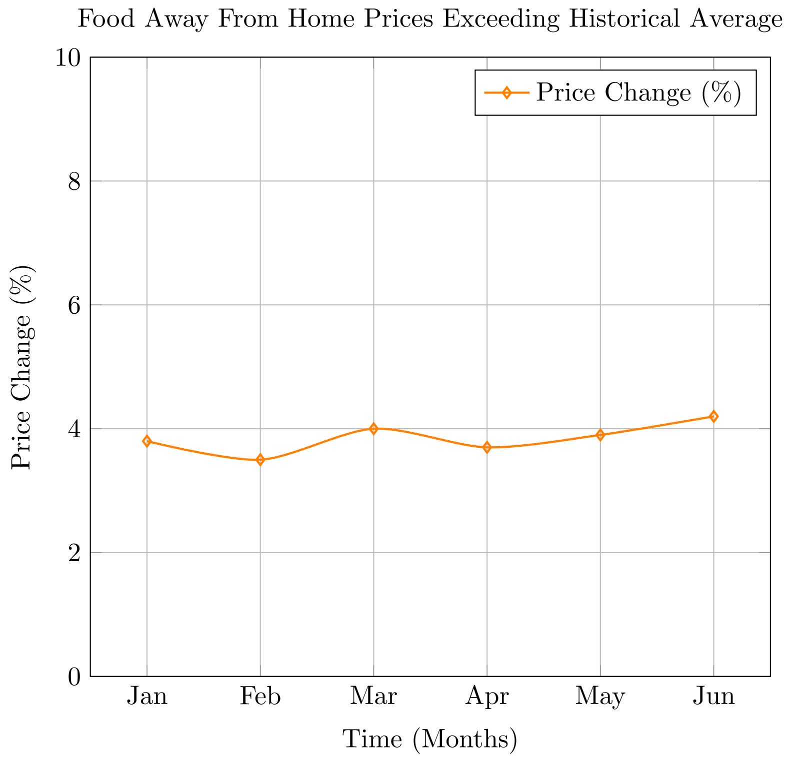


Figure 3: Trend of Food Away From Home Prices Exceeding Historical Average

- Year-over-year change: 3.8%.

Assumptions:

$$P(A) = 0.6 \quad \text{(Frequent exceeding of the average historically).}$$

$$P(B|A) = 0.7 \quad \text{(High year-over-year change often exceeding averages).}$$

$$P(B) = 0.5 \quad \text{(Overall occurrence of year-over-year change ¿3\%).}$$

Bayes' Theorem Calculation:

$$P(A|B) = \frac{P(B|A) \cdot P(A)}{P(B)} = \frac{0.7 \cdot 0.6}{0.5} = 0.84$$

Conclusion: There's an 84% chance that "Food Away From Home" prices will exceed the historical average in 2024.

5 Conclusion

1. **Adapting to Market Changes:** By continually updating price change probabilities based on new market data, Bayesian methods help analysts remain responsive to evolving food

price trends.

2. **Making Informed Forecasts:** Bayesian analysis provides a quantitative foundation for predicting food price movements, enabling stakeholders to make data-driven decisions about market strategies and resource allocation.

3. **Communicating Price Trends:** Bayesian models visually represent relationships between market variables, making it easier to explain complex price dynamics and uncertainties to stakeholders.

4. **Leveraging Expert Knowledge:** Bayesian methods allow for the incorporation of expert insights on factors influencing food prices, which is particularly valuable in situations where historical data is limited or market conditions are volatile.

6 References

U.S. Department of Agriculture, Economic Research Service.
Food Price Outlook.
Available at: https://catalog.data.gov/dataset/food-price-outlook.