

Forecasting Monthly Grocery Sales

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Data Management & Modelling

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Introduction

- Accurate sales forecasting is important for grocery retailers because it helps manage inventory, reduce waste, plan staffing needs, and improve profitability.
- This project focuses on predicting next year's monthly grocery sales by analyzing historical data containing product information, sales records, cities, countries, and employee details.
- We applied excel, powerBi, and certain forecasting techniques to understand trends, seasonality, and product-level differences in demand.
- Tools Used: Excel, Power BI

Problem Statement

- The goal of this project is to build a data model that forecasts monthly grocery sales for the top 5 products.
- The dataset includes multiple related tables (Sales, Products, Employees, Cities, Countries), allowing analysis from several perspectives.
- We aim to identify:
 - Seasonality patterns
 - Time trends
 - Product, store, and geographic differences in sales

DataSet Overview

Table Name	# Columns	Purpose
Sales	5	Tracks monthly quantity sold & discounts
Products	9	Product name, Product Price, class, allergen info
Employees	8	Employee demographics & location
Cities	4	City name, zip code, and the country it belongs to
Countries	3	Country name, id, and code
Products Category	2	Products category names and their IDs.

DataSet Overview

Merged tables

- Sales
- Products
- Employees,
- Cities
- Countries

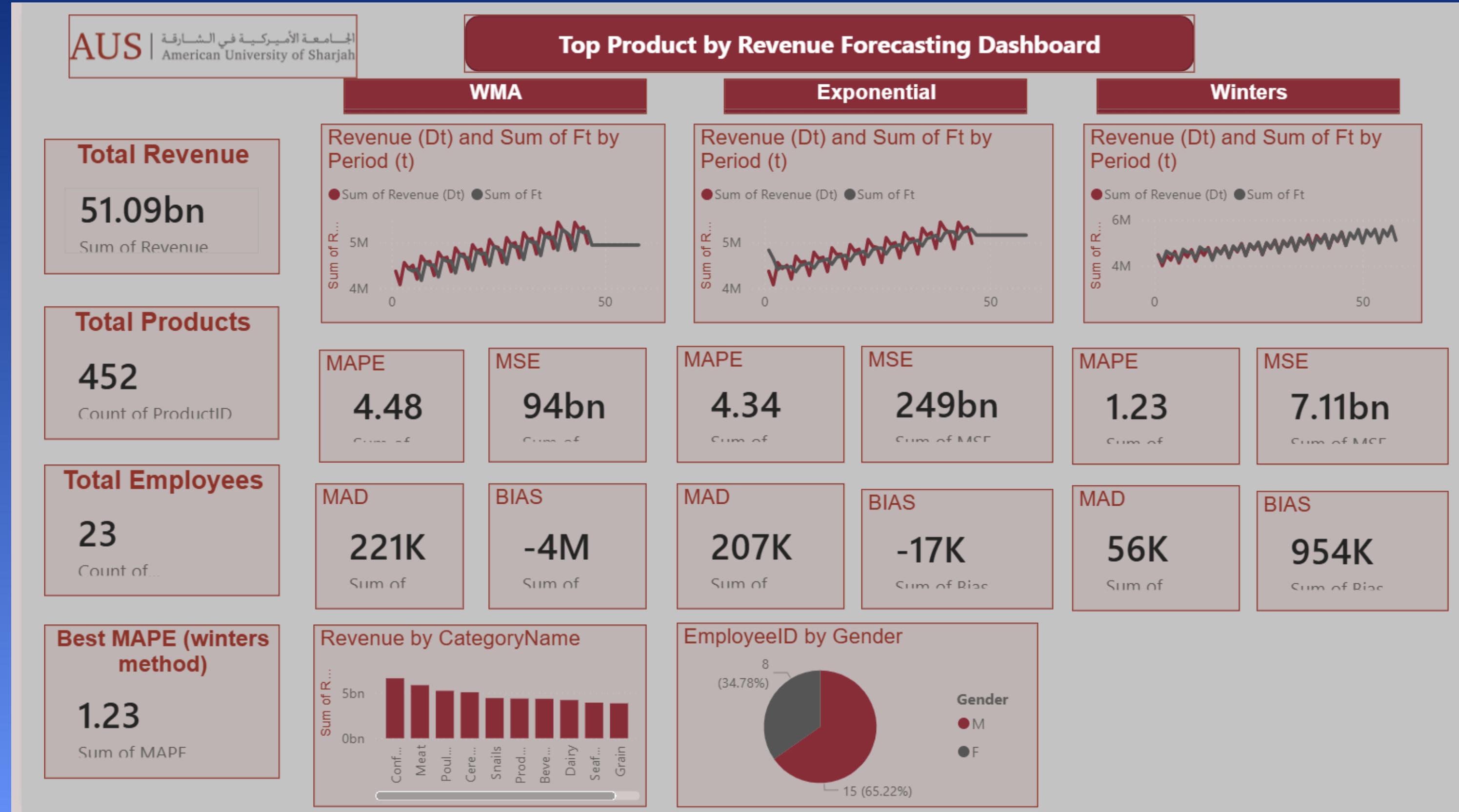
Combined using foreign keys

- ProductID
- CityID
- CountryID

Data Cleaning & Preprocessing

- After merging, we used Pivot Tables in Excel to analyze each product's total revenue over the last 4 years.
- We sorted products in descending order of revenue and selected the Top 5 Products with the highest total revenue.
- These top products were chosen for forecasting because they have the greatest financial impact on the company.
- For each selected product, we extracted its monthly revenue and created a dedicated sheet to apply forecasting models.

PowerBI Dashboard



Forecasting Techniques Used

We applied three forecasting methods to each product's monthly revenue:

Weighted Moving Average (WMA)

- Uses weights W_1, W_2, W_3 to give more importance to recent data.
- Good for short-term trend following.

Exponential Smoothing

- Uses alpha (α) to smooth the data.
- Gives more weight to recent observations but keeps the entire history.

Winters Method (Holt-Winters)

- Uses alpha (α), beta (β), and gamma (γ).
- Captures level, trend, and seasonality, making it best for periodic data.

Error Metrics Calculated

- MAD: Mean Absolute Deviation
- MSE: Mean Squared Error
- MAPE: Most important — shows % forecast error
- Bias: Indicates over-forecasting or under-forecasting

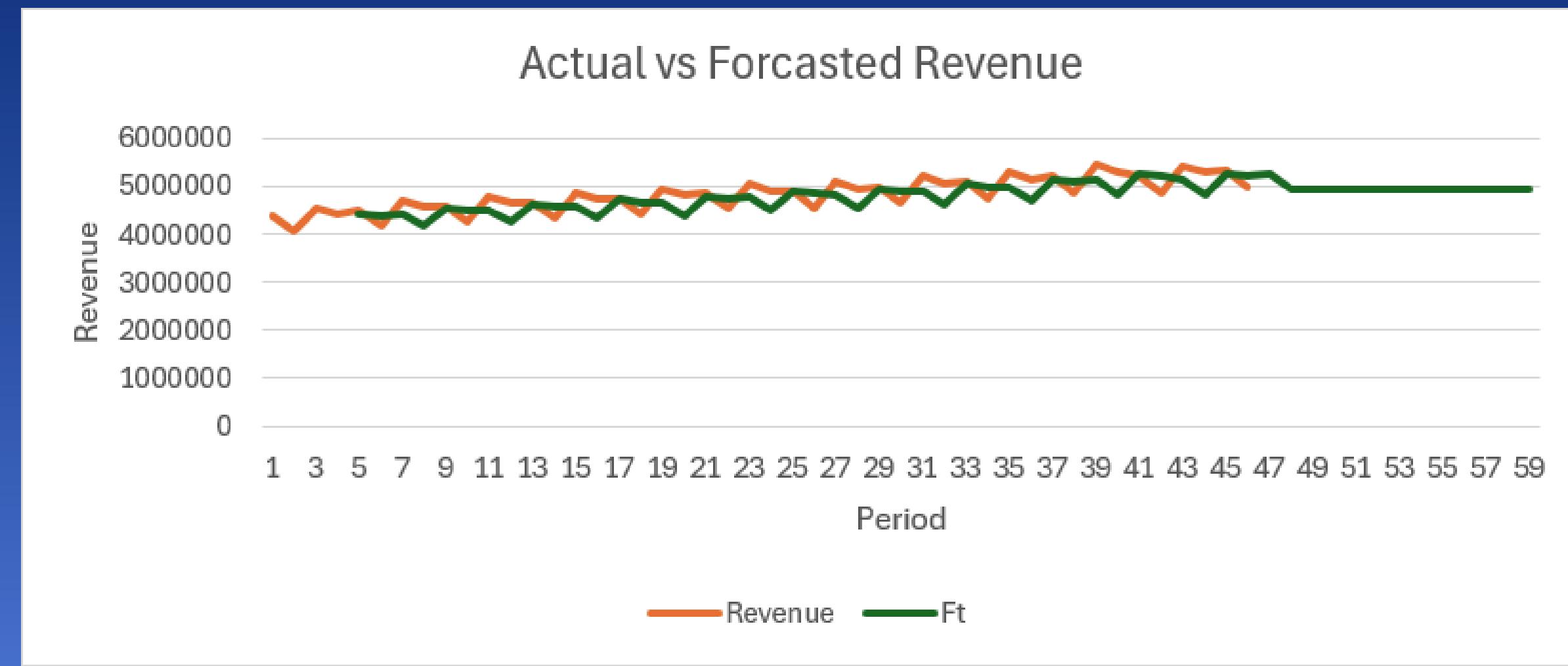
Product 345 – WMA Forecasting Results

WMA applied using weights:

W1	W2	W3
0.85218304	0.12763	0.00361

Error Metrics:

MSE	94453307121
MAD	220545.6386
MAPE	4.484847299
Bias	-4052237.565



The Weighted Moving Average captures the overall upward revenue trend but reacts slowly to sharp fluctuations.

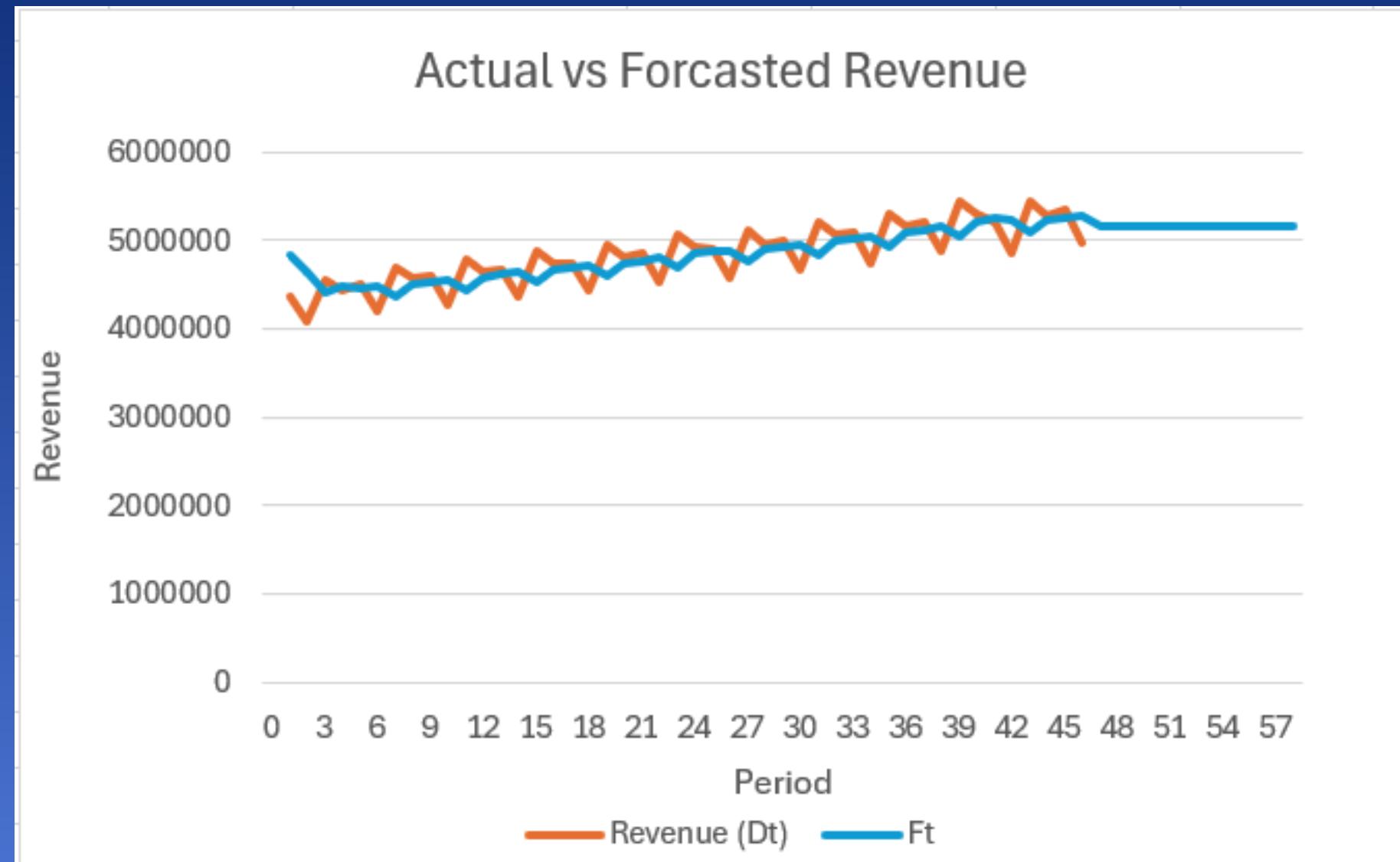
- Forecasted values stay close to the actual revenue, showing reasonable short-term accuracy.
 - MAPE of 4.48% indicates a moderate forecast error — acceptable but not the most accurate among the methods.
 - High negative bias suggests that WMA under-forecasts revenue on average.
 - Compared to Exponential Smoothing and Winters Method, WMA performs weaker due to limited ability to capture trend and seasonality.
- W1 has the highest weight (0.85), meaning the model relies heavily on the most recent month.

Product 345 – Exponential Smoothing Results

alpha
0.41121

Error Metrics:

MSE	248702961300
MAD	207204.6225
MAPE	4.342823203
Bias	-17275.21742



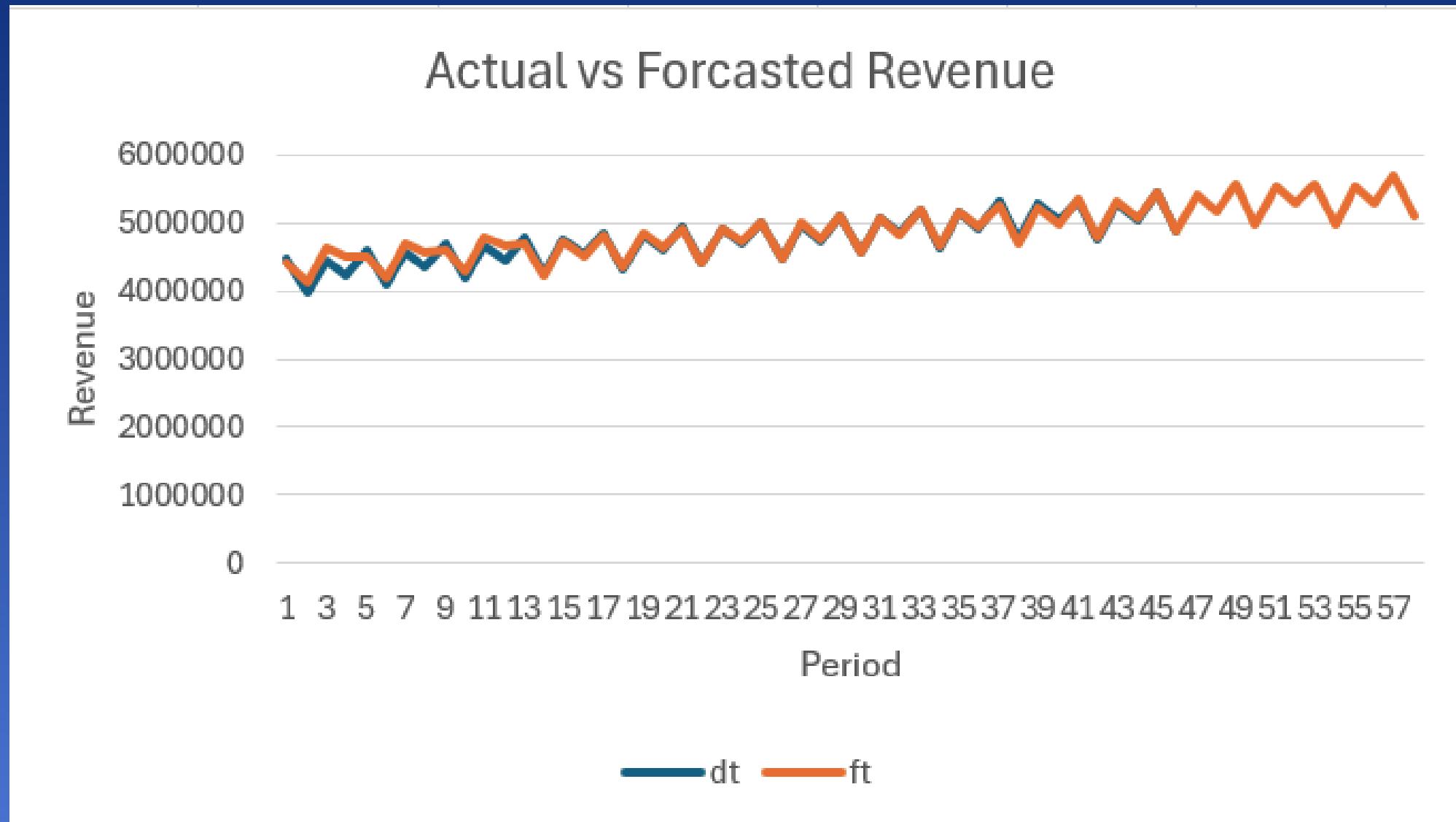
- With $\alpha = 0.41121$, the method gives significant weight to recent revenue while still smoothing out noise.
- The forecast line closely follows the actual revenue, showing better responsiveness than WMA.
- MAPE of 4.34% indicates a slightly lower percentage error compared to WMA, meaning improved accuracy.
- Smaller negative bias shows the model still slightly under-forecasts but much less severely than WMA.
- Overall, Exponential Smoothing performs better for this product because it adapts more quickly to changes in the revenue trend.

Product 345 – Winters Method Results

alpha	beta	gamma
0.002	0.68874	0.838048802

Error Metrics:

MSE	7.106E+09
MAD	55788.062
MAPE	1.2280691
Bias	953539.32



- Winters Method incorporates level, trend, and seasonality, making it the most sophisticated model among the three.
- The forecast (Ft) follows the actual revenue almost perfectly across the entire period, showing very high accuracy.
- MAPE = 1.22%, which is significantly lower than WMA and Exponential Smoothing — meaning the percentage error is extremely small.
- Very low MAD and moderate positive bias indicate the model slightly over-forecasts but stays consistently close to actual values.
- The combination of $\alpha = 0.002$, $\beta = 0.6887$, and $\gamma = 0.838$ captures both long-term trend and seasonal fluctuations effectively.
- Overall, Winters Method is the best-performing model for this product and provides the most reliable forecast.

Best Method Overall for the Company

Winters Method (Holt-Winters)

- the best forecasting method across all top products, because it captures both trend and seasonality.
- It produced the lowest error, the smallest MAD, and the lowest MAPE.

Overall Model Comparison

- All five products showed seasonal patterns in their monthly revenue.
- Winters Method outperformed WMA and Exponential Smoothing for every product.
- Winters achieved extremely low MAPE values (as low as 0.20%) compared to WMA (up to 11.47%).
- Exponential Smoothing provided moderate accuracy but it was hard to capture seasonality.
- WMA was consistently under-forecasted and produced the highest error and this was reflected in the bias.

Managerial Insights

- The Winters Method should be adopted as the company's primary forecasting tool, as it consistently produced the most accurate predictions across all top 5 products.
- Products 149, 104, and 392 show strong seasonal patterns, forecasts can be used to increase inventory before peak months and reduce overstocks during low-demand periods.
- Highly accurate forecasts ($MAPE < 1\%$ for most products using Winters) allow management to:
 - Optimize purchasing schedules
 - Adjust warehouse capacity during seasonal peaks
 - Improve staffing and labor allocation
 - Overall, the company can reduce costs, eliminate stockouts, and improve availability through data-driven planning.

Challenges and Limitations

- Exponential smoothing and wma didnt perform as well since they dont factpr in trend and seasonality, which means some models worked better than others, which is indicated by MAPE
- Since the data came from many different tables, there was a small chance of mistakes when merging them together.
- The dataset was too large so we had some issues working with the dataset at first since Excel was crashing.

Conclusion

- Overall, the analysis demonstrates that data-driven forecasting improves reliability, reduces uncertainty, and supports proactive operational planning.
- This project showed us how data analytics and forecasting can help a company plan better, reduce mistakes, and make smarter decisions in areas like inventory, purchasing, and staffing.
- Across all five products, the Winters Method consistently delivered the lowest error rates, confirming that seasonality plays a major role in grocery sales.
- Exponential Smoothing provided moderate accuracy but was less effective for products with strong seasonal trends.