Product Demand Estimation

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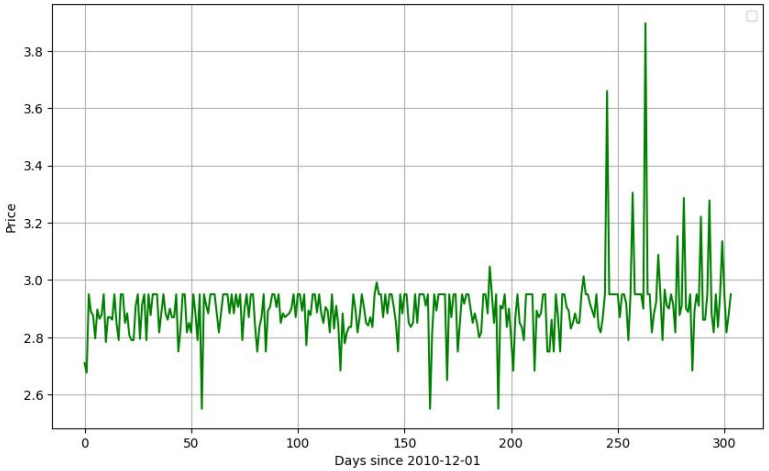
Agenda

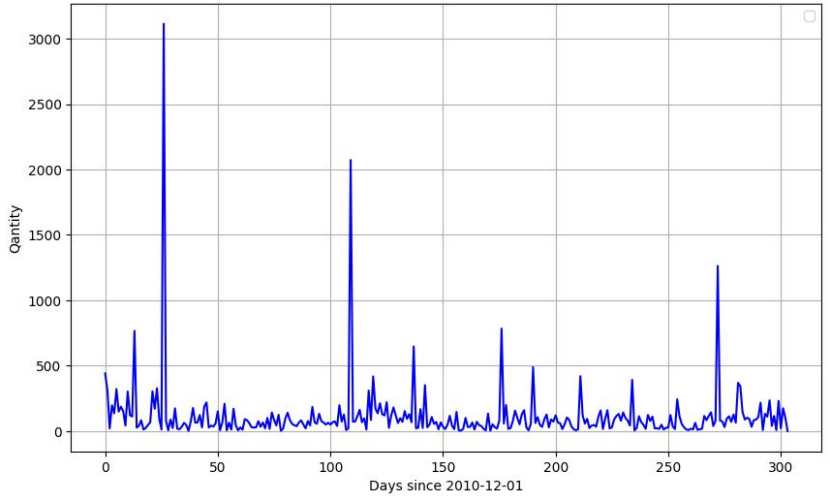
1. Data Exploration and Processing
2. Product Demand Estimation Model and Evaluation
3. Estimation Model on Price Plan

Data Exploration and Processing

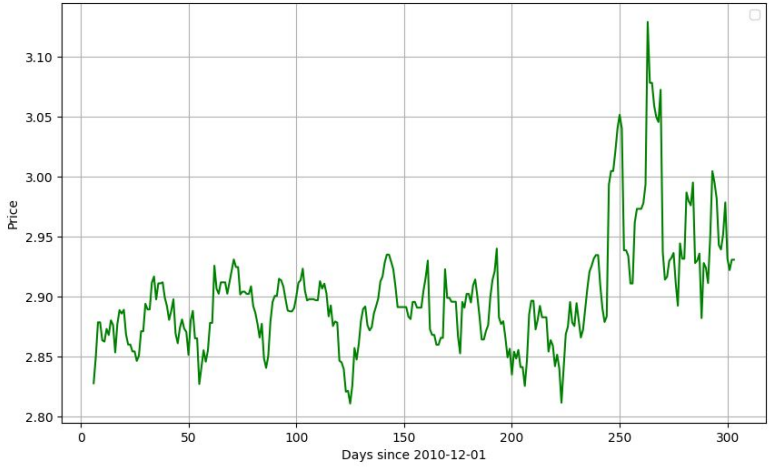
1. Select UK Data
2. Remove Missing and Invalid Values (e.g. Unit Price < 0)
3. Get Top 20 Products w.r.t Revenues
4. Remove Irrelevant Columns (InvoiceNo, CustomerID, Description)
5. Get Sold Quantity and Price for each Product per InvoiceDate
6. Smooth Price and Quantity
7. Remove Outliers from Training Data (80% of the total)

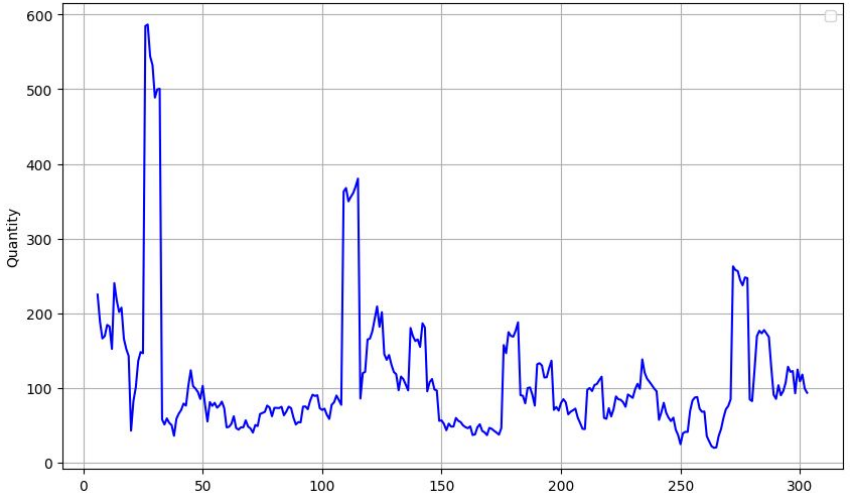
Initial





Smoothed by Past 7 days' Average





Log-Log Product Quantity Estimation for Each Product by Regression Model

1. Naive Regression with Current Price: $\ln Q = \alpha + \beta \ln P + \epsilon$

2. Current Prices + Recent Pricing Distribution

$$\ln Q_t = \beta_0 + \beta_1 \ln P_t + \beta_2 \ln \mu_{t-1} + \beta_3 \ln \sigma_{t-1} + \epsilon_t$$

3. Current Prices + Recent Pricing + Current Seasonality:

$$\ln Q_t = \beta_0 + \beta_1 \ln P_t + \beta_2 \ln \mu_{t-1} + \beta_3 \ln \sigma_{t-1} + \sum_{k=1}^{K} \left[\gamma_k \cos\left(\frac{2\pi k t}{T}\right) + \delta_k \sin\left(\frac{2\pi k t}{T}\right) \right] + \epsilon_t$$

Evaluate Regression Model

Metrics: R-squared Score (closer to 1 -> the Better Model)

No Smoothing

StockCode	Naive Regression	Regression with Previous Days	Regression with Previous Days + Seasonality
(85123A)	-0.21	-0.20	-0.14
(84879)	0.43	0.44	0.54
(22086)	-0.05	0.24	0.20
(22386)	-0.03	0.24	0.27
(82484)	-0.04	-0.10	-0.09
(22470)	-7.13	-6.70	-5.28
(85099B)	-0.06	0.10	0.04
(79321)	0.25	0.42	0.42
(22197)	-0.14	-0.04	0.05
(22502)			
(22178)	0.01	0.13	0.14
(85099F)	-0.24	-1.15	-1.43
(21137)	0.12	0.19	0.26
(22423)	0.18	0.16	0.22
(47566)	0.19	0.30	0.54
(23166)	0.09	-0.02	-0.23
(23284)	0.15	0.13	0.12
(23298)	0.25	0.28	0.27
(23203)	0.32	0.30	0.34
Mean R-squared	-0.33	-0.29	-0.21

Smooth by 7-day Average

StockCode	Naive Regression	Regression with Previous Days	Regression with Previous Days + Seasonality
(85123A)	-0.12	-0.09	0.19
(84879)	0.45	0.44	0.65
(22086)	0.06	0.43	0.88
(22386)	0.01	0.13	0.23
(82484)	-0.13	-0.01	0.03
(22470)	-0.04	0.13	0.28
(85099B)	0.04	0.43	0.59
(79321)	0.05	0.45	0.52
(22197)	-0.03	0.15	0.51
(22502)			
(22178)	-0.06	0.00	0.32
(85099F)	0.08	0.14	0.39
(21137)	-0.19	-0.05	0.46
(22423)	0.01	0.05	0.35
(47566)	-1.05	-1.67	0.39
(23166)	0.64	0.79	0.86
(23284)	-0.09	-0.16	0.12
(23298)	0.38	0.42	0.56
(23203)	0.15	0.25	0.44
Mean R-squared	0.01	0.10	0.43

Smooth by 7-day Average

StockCode	Naive Regression	Regression with Previous Days	Regression with Previous Days + Seasonality
(85123A)	-0.12	-0.09	0.19
(84879)	0.45	0.44	0.65
(22086)	0.06	0.43	0.88
(22386)	0.01	0.13	0.23
(82484)	-0.13	-0.01	0.03
(22470)	-0.04	0.13	0.28
(85099B)	0.04	0.43	0.59
(79321)	0.05	0.45	0.52
(22197)	-0.03	0.15	0.51
(22502)			
(22178)	-0.06	0.00	0.32
(85099F)	0.08	0.14	0.39
(21137)	-0.19	-0.05	0.46
(22423)	0.01	0.05	0.35
(47566)	-1.05	-1.67	0.39
(23166)	0.64	0.79	0.86
(23284)	-0.09	-0.16	0.12
(23298)	0.38	0.42	0.56
(23203)	0.15	0.25	0.44
Mean R-squared	0.01	0.10	0.43

Smooth by 14-day Average

StockCode	Naive Regression	Regression with Previous Days	Regression with Previous Days + Seasonality
(85123A)	0.00	-0.03	0.43
(84879)	0.53	0.52	0.78
(22086)	0.21	0.74	0.94
(22386)	0.00	0.14	0.87
(82484)	-0.31	-0.79	-0.84
(22470)	-0.01	0.28	0.38
(85099B)	-0.11	0.20	0.56
(79321)	-0.22	0.05	0.31
(22197)	-0.01	0.17	0.61
(22502)			
(22178)	-0.13	0.06	0.58
(85099F)	-0.09	-0.09	0.60
(21137)	0.36	0.39	0.64
(22423)	-0.01	0.04	0.52
(47566)	-0.91	-2.73	0.65
(23166)	0.55	0.82	0.86
(23284)	-0.03	0.12	0.61
(23298)	0.69	0.65	0.78
(23203)	0.28	0.33	0.76
Mean R-squared	0.04	0.05	0.56

Evaluate Regression Model

Observations:

1. Consider Previous Days' Pricing Distribution and Seasonality in Models
2. Smooth Pricing Data

More Features to the Regression Model?

1. Customer Groups
2. Competitors / Supplement Effects

How to Use the Model in Price Plan

1. Check Elasticity (How does price change affect product demand?)

   Customers are sensitive to price change

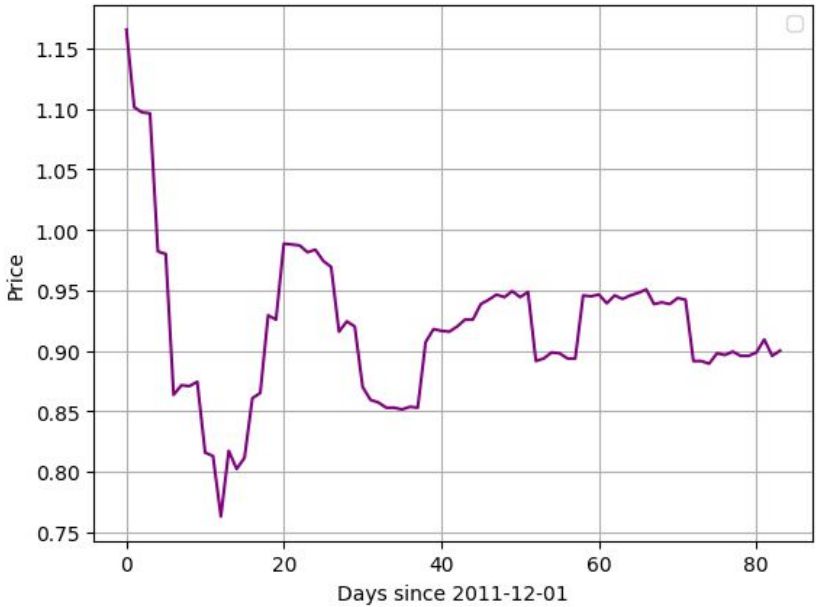
2. Estimate Demand from New Prices

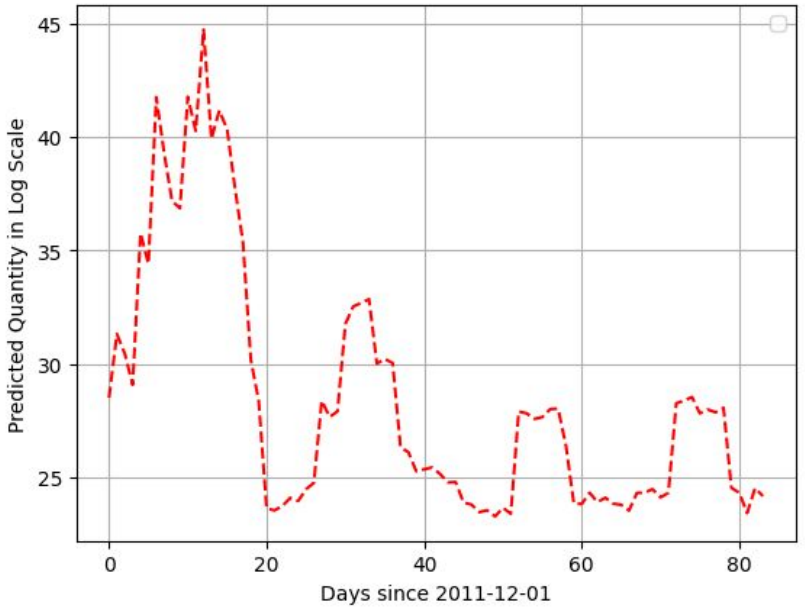
$$\ln Q_t = \beta_0 + \beta_1 \ln P_t + \beta_2 \ln \mu_{t-1} + \beta_3 \ln \sigma_{t-1} + \sum_{k=1}^{K} \left[\gamma_k \cos\left(\frac{2\pi k t}{T}\right) + \delta_k \sin\left(\frac{2\pi k t}{T}\right) \right] + \epsilon_t$$

StockCode	Elasticity
85123A	-1.86
84879	-71.26
21212	-9.91
21977	-9.63
85099B	-28.31
22197	-26.03
22178	-6.73
22616	-3.92
17003	-4.13
84077	-4.10

Estimate Demand for 2011/12 - 2012/03

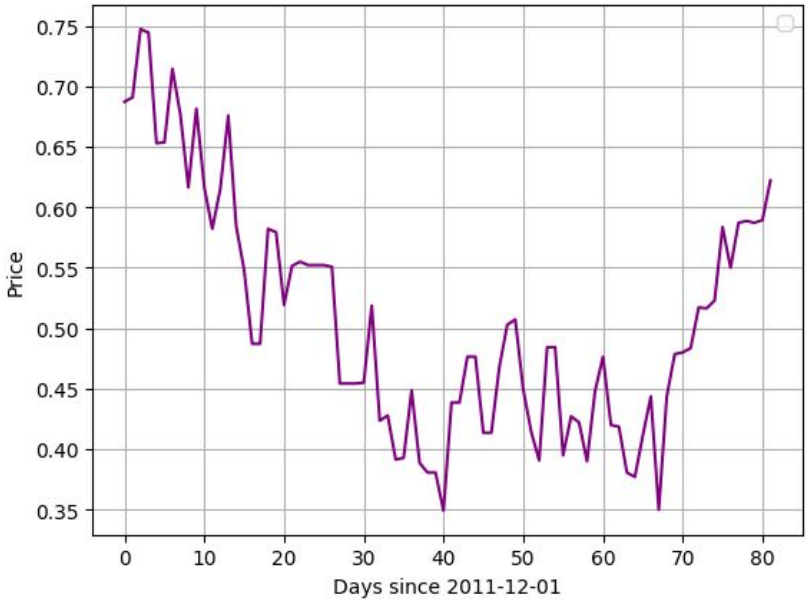
ASSORTED COLOUR BIRD ORNAMENT: R-Squared = 0.73

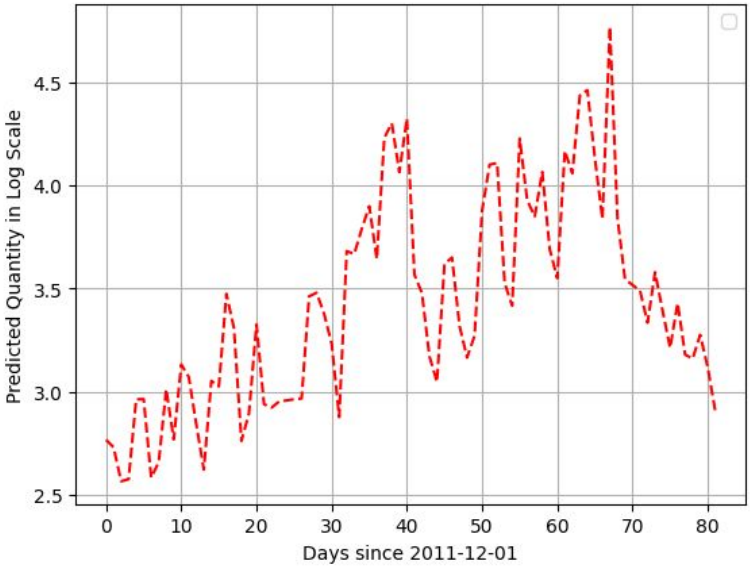




Estimate Demand for 2011/12 - 2012/03

PACK OF 12 LONDON TISSUES: R-squared = 0.41





Conclusion from Price Plan

StockCode	Model Metrics	Elasticity	Old Price	New Price	Old Revenue	New Revenue	Revenue Increase
85123A	0.56	-1.86	2.9	4.5	343.72	35.24	-308.48
84879	0.73	-71.26	1.68	0.92	195.91	3.44e+17	3.44E+17
21212	0.39	-9.91	0.55	10.39	63.72	inf	
21977	0.55	-9.63	0.55	0.7	51.92	17230.21	17178.29
85099B	0.69	-28.31	2.01	1.6	315.04	188728.07	188413.03
22197	0.50	-26.03	0.84	1.84	136.1	1.04e+91	1.04E+91
22178	0.53	-6.73	1.42	1.88	113.41	208.94	95.53
22616	0.41	-3.92	0.32	0.51	38.76	17.76	-21
17003	0.68	-4.13	0.31	0.15	51.67	158.79	107.12
84077	0.52	-4.1	0.29	4.03	67.95	3.44e+10	34399999932

1. Recommended for Sales: the new price plan will increase overall revenue.

2. What could be changed?
   A bit more price reduction on highly sensitive products can lead to more revenues.

Reference

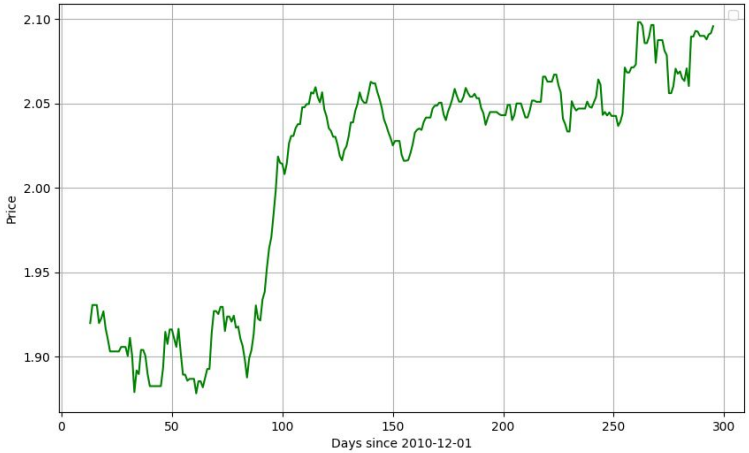
Code: https://github.com/t07902301/Price-Elasticity

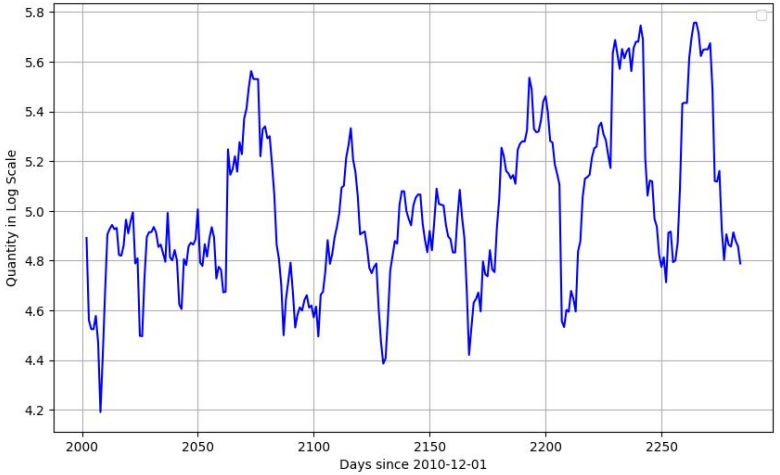
A guide to price elasticity – the key to optimal prices

Modeling Variable Seasonal Features with the Fourier Transform

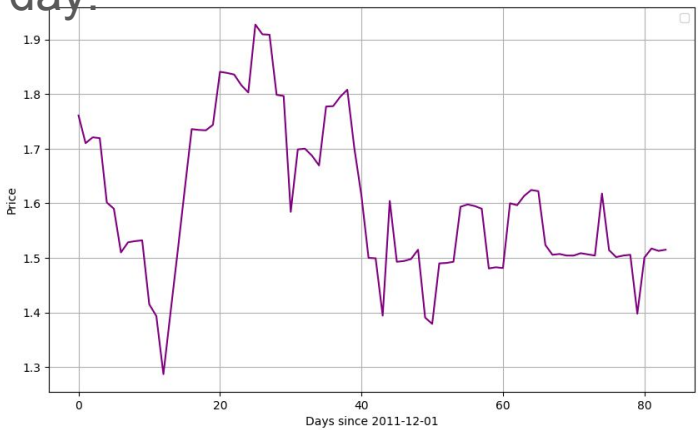
JUMBO BAG RED RETROSPOT: Elasticity = -28

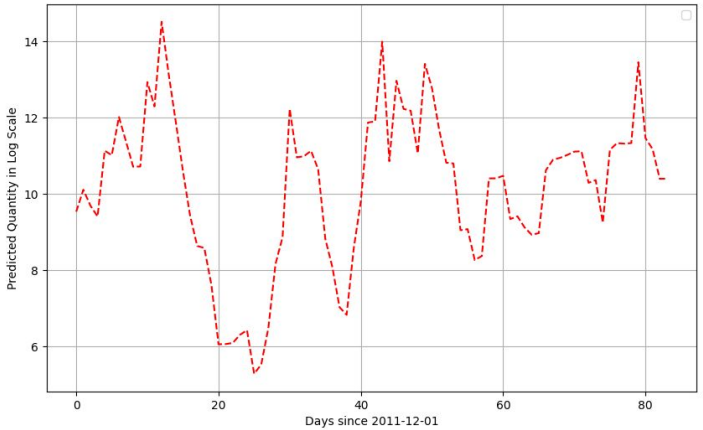
Revenue per day: 315





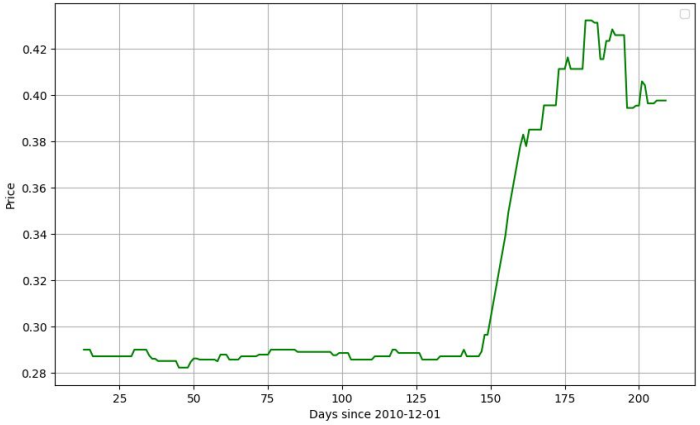
Revenue per day: 188728

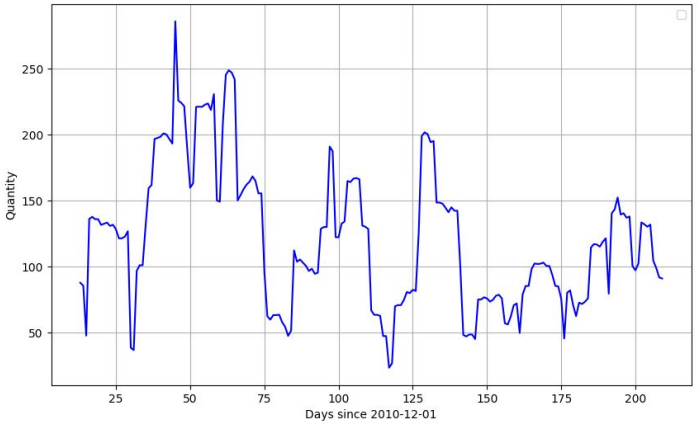




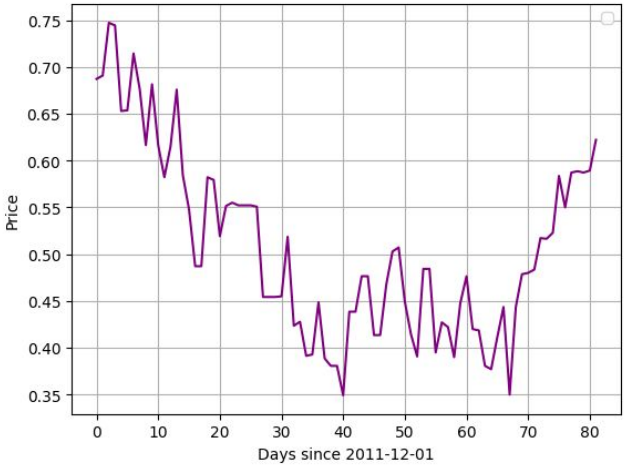
Revenue per day: 38.76

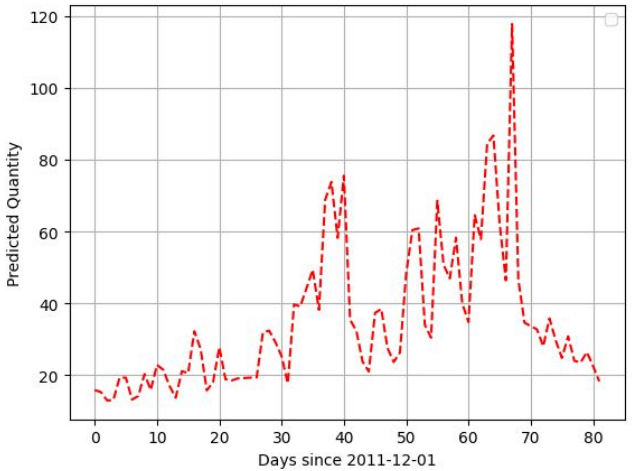
PACK OF 12 LONDON TISSUES: Elasticity = -3.92





Revenue per day: 17.76





Conclusion

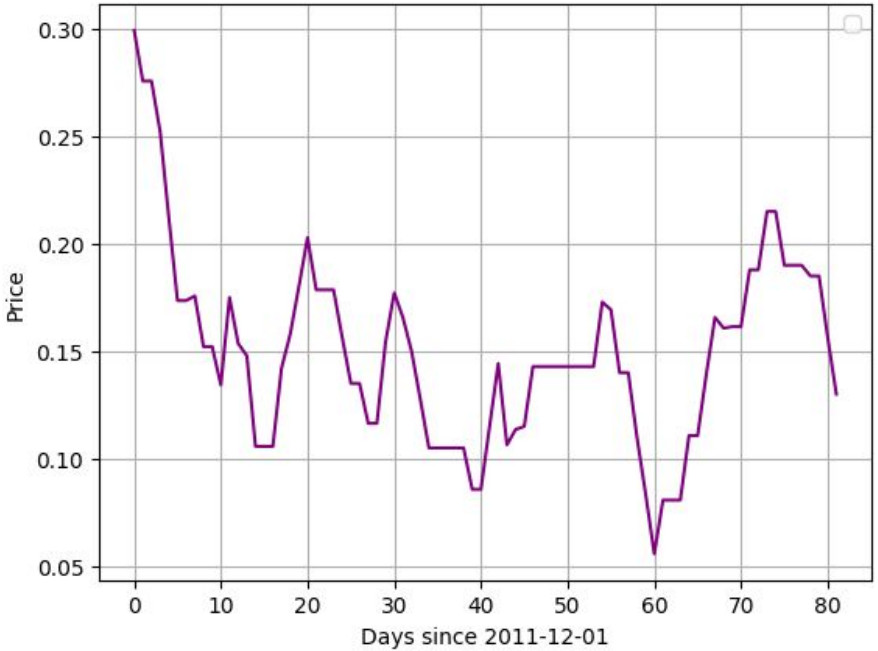
More insightful demand estimation for the overall revenue strategy.

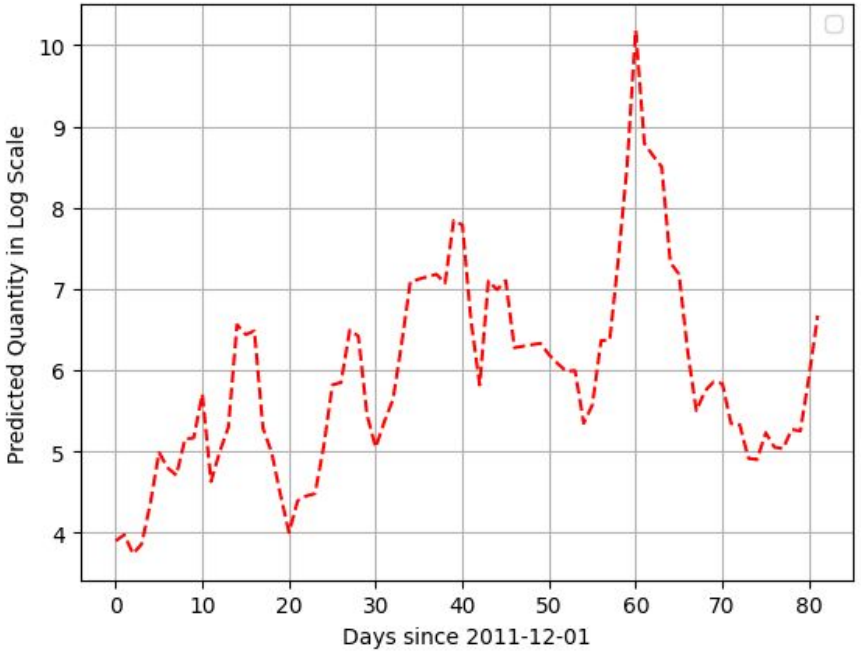
More Forecasting Features?

1.

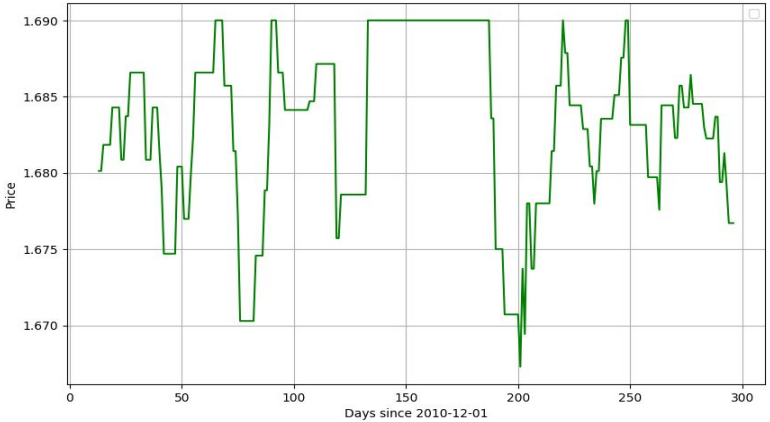
Estimate Demand for 2011/12 - 2012/03

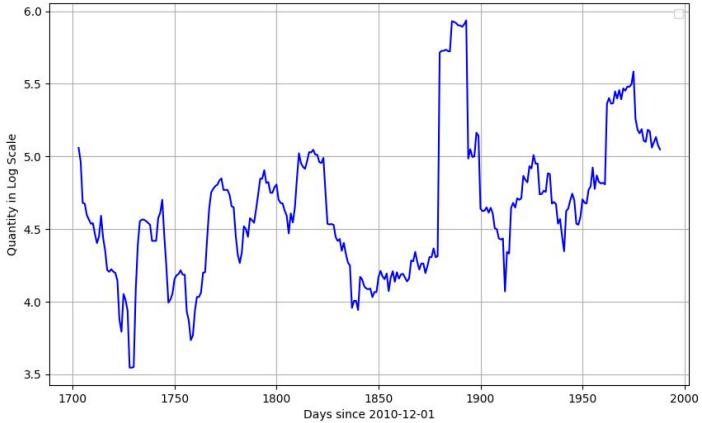
BROCADE RING PURSE: R-Squared = 0.68

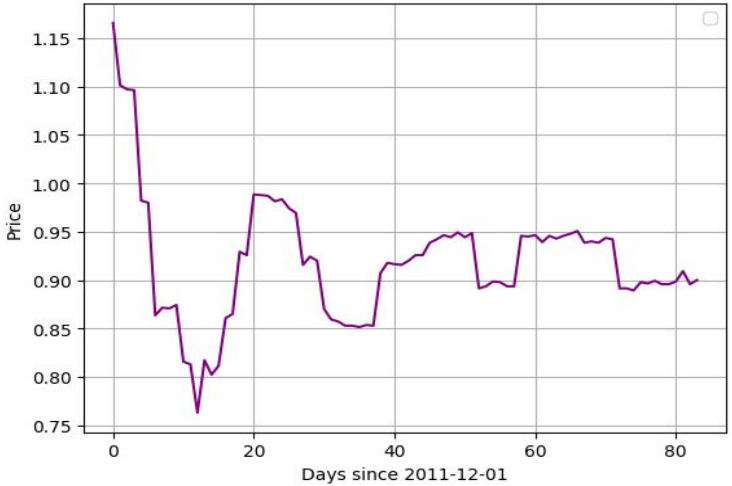


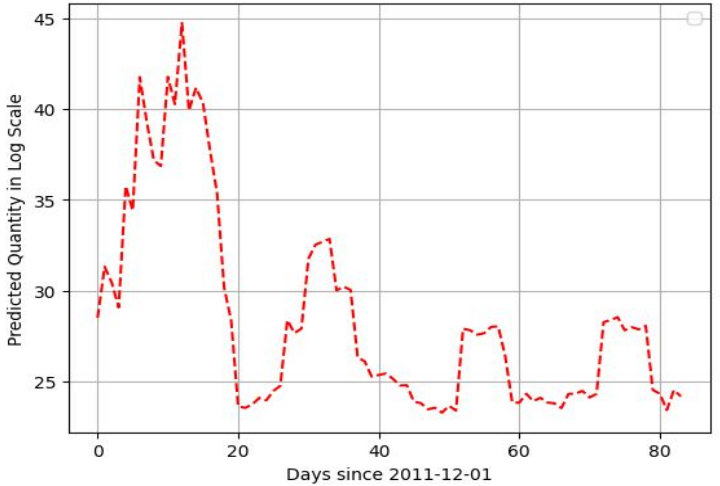


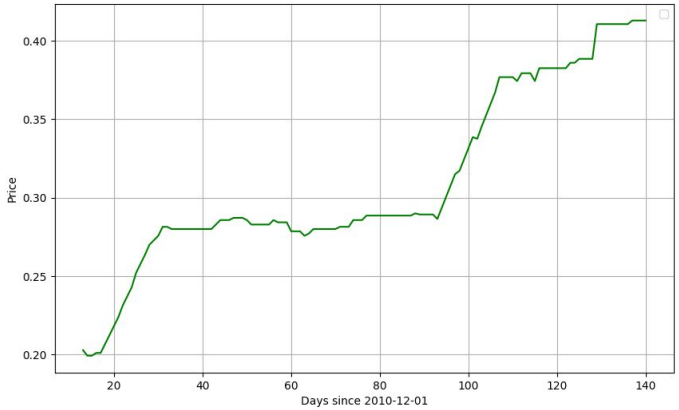
ASSORTED COLOUR BIRD ORNAMENT: Elasticity = -71

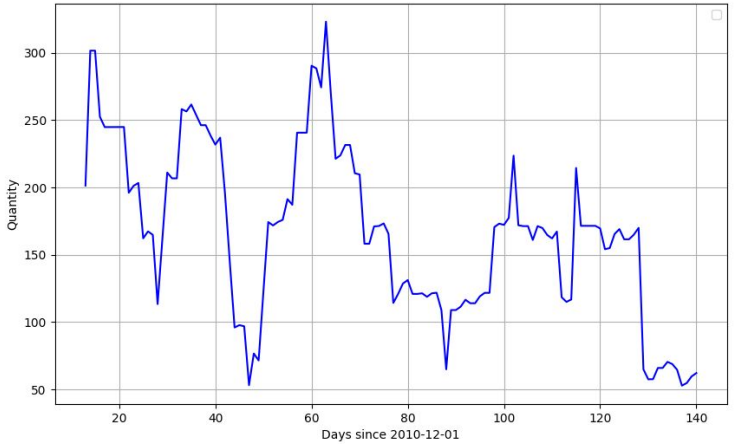


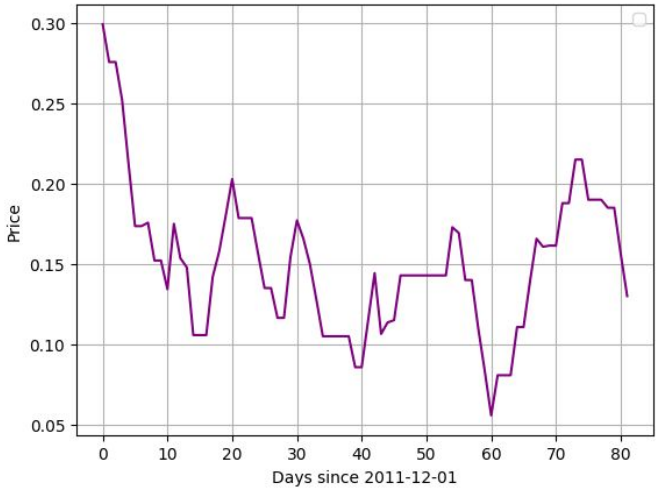


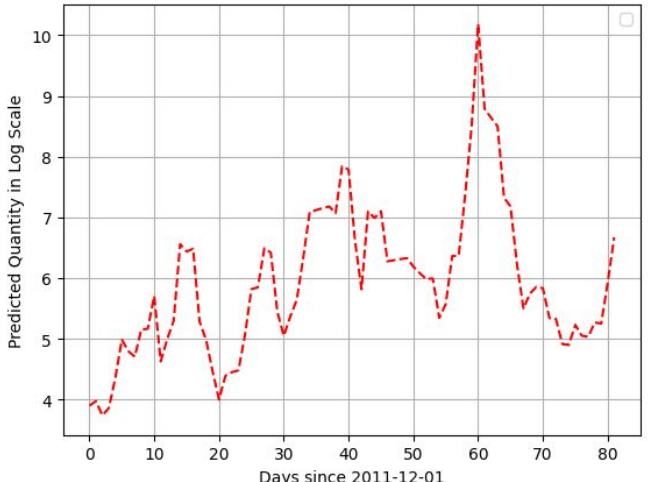





Price
Days since 2010-12-01


Quantity
Days since 2010-12-01


Price
Days since 2011-12-01


Predicted Quantity in Log Scale
Days since 2011-12-01