MKT 680 - Marketing Analytics

Project Report:
Pricing Models

Team 4

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1. Introduction

1.1 Business Background

ACSE Supermarket is a supermarket chain in Lunitunia with over 40 stores and revenue of $6 billion. In order to promote sales on a more personal level, our consulting team is tasked to investigate the strategy of personalized promotions using ACSE dataset. In this pricing adjustment project, we aim to adjust shelf prices of selected products using pricing models in order to improve revenue.

Before we dig into the ACSE data, we want to first introduce the concept of price sensitivity, which is also known as price elasticity. Price elasticity of demand is a measurement of the change in the consumption of a product in relation to a change in its price[1], and to express mathematically, it is:

$$Price\ Elasticity\ = \frac{\%\ Change\ in\ Quantity\ Demanded}{\%\ Change\ in\ Price}$$

If an item has a price elasticity less than -1, the item will be considered as elastic (very price sensitive); if an item has a price elasticity greater than -1, the item will be considered as inelastic (less price sensitive). By implementing the idea of price sensitivity, we can measure how an individual product responds to price change and also target certain products with higher price sensitivity.

Next, ACSE is investigating an everyday-low-price (EDLP) strategy, which is defined by a pricing strategy promising consumers a low price without the need to wait for sale price events or comparison shopping, and a retail store sets a low price and maintains it over a long time-horizon[2]. It is common for products with *high* price elasticity to use EDLP strategy. Thus, in this project, our team will identify EDLP products in ACSE Supermarket and suggest strategies and actionable business plans for further personalized promotion.

1.2 Challenge

Our analytics consulting team was selected by ACSE to adjust list (shelf) prices to improve revenue. ACSE is investigating an everyday-low-price (EDLP) strategy on up to 50 products across all ACSE stores. ACSE also understands that an EDLP strategy will likely require investments in price reductions across the 50 products and would like to fund the investment with price increases on 100 less price sensitive products.

Our price change recommendations should report to ACSE the following (on a one year basis):

- a list of 150 products with recommended price changes and justifications
- expected changes in sales quantity, revenue and profitability for each store and overall across all stores

[1] "Price Elasticity of Demand", www.investopedia.com/terms/p/priceelasticity.asp
[2] "EDLP", corporatefinanceinstitute.com/resources/knowledge/economics/edlp/

2. Data Understanding

2.1 Data Cleaning and Data Preparation

The datasets we will be using are ACSE transaction data and ACSE product data. There are 1.2 billion observations and 8 variables covering the transactions data with customer ID, store ID, and sales amount. The product table contains 155,919 observations and 10 variables, including products' categories, subcategories, and descriptions.

In order to identify products that have a significant share of the sales, we first calculated the cumulative percentage of total sales across products using transaction data, which is calculated by the cumulative revenue of each product divided by the total revenue of all products. The result will be shown in the EDA part larter in the report.

2.1.1 Transaction Price

Then we select our highly demanded products, which we define as products that have a cumulative percentage of total sales less than 0.3 (products that comprise the top 30% of total sales). This will give us a total of 513 unique products. After merging back to the original transaction data, we now have 378.5 millions observations, with transaction date, prod ID, sales amount, sales quantity, and sales weight. Furthermore, we also calculate the price for each transaction: if the sales weight equals to 0, we have the price the same as sales amount; if the sales weight does not equal to 0, we have the price as the sales amount divided by sales weight. We can use this dataset to do further analysis on EDLP and pricing regression models, and below is the top five rows of our highly demanded products table:

	trans_dt	prod_id	sales_amt	sales_qty	sales_wgt	quantity	price
144687961	2018-05-12	20426078001	3.11	1	0.84	0.84	3.702381
360496369	2020-10-04	21097012001	1.79	1	0.00	1.00	1.790000
283139916	2020-01-16	20704361001	5.99	1	0.00	1.00	5.990000
231238463	2019-07-24	20049778001	3.99	1	0.00	1.00	3.990000
59632602	2018-08-19	20007535001	2.09	1	0.19	0.19	11.000000

Figure 1: Highly demanded products table

2.1.2 Converting to Weekly Basis

Next, we notice that the transaction data is on a daily basis, whereas for most of the products, they do not have transaction data everyday. In order to smooth out the noise in the date feature, we decided to transform the transaction date from daily basis to weekly basis. In this way, we can compute the price elasticity for each individual product each week, and we can also use the weekly data to set our uncontrollable factors (such as seasonality) in our later response function.

2.1.3 List Price, Discounted Price, and Demand

Besides the dates, there are some other features we create that relate to discount price, list price, and demand:

- **list_price**: highest price (which we calculated from sales quantity and sales amount) for each product
- **weekly_demand**: sum of weekly's quantity for each product
- **discounted_price**: weekly total revenue divided by weekly_demand (weekly total quantity) for each product
- **weekly_amount**: weekly revenue for each product (discounted_price * weekly_demand)
- **discounted_price_pct**: the percentage change in discounted price comparing to previous time period for each product
- **weekly_demand_pct**: the percentage change in demand comparing to previous time period for each product
- **discount_level**: the percentage change in discounted price comparing to list_price, calculated by (list_price - discounted_price) / list_price

2.1.4 Complement Price, Substitute Price, and Competitor Price

The price of complements and substitutes are also important for price response function. Here, we use cross-price elasticity to identify if a product is complement or substitute to another product, the cross-price elasticity function is as below:

$$Cross\ Price\ Elasticity\ of\ Demand = \frac{\%ChangeinQuantityDemandedforGoodA}{\%ChangeinPriceofGoodB}$$

If the value of cross-price elasticity is negative, then good A and good B are complements, since an increase in demand for A is accompanied by an increase in the quantity demanded of B. In contrast, good A and good B are substitutes when the value of cross-price elasticity is positive, since price increases of A cause a rise in demand for B.[3]

Aligned with the aforementioned definitions of complements and substitutes, we firstly create a new table of all the possible product pairs, and then we calculate the cross-price elasticity for each product on a weekly basis. A sample table of paired products with their cross-price elasticity is shown below. If the cross-price elasticity is greater than 1, we consider those products as substitutes, and we average the discounted price for all the substitutes as the substitute price of the target product. If the cross-price elasticity is less than 1, we consider those products as complements, and we also average the discounted price for all the complements as the complement price of the target product.

[3]"Other Demand Elasticities", courses.lumenlearning.com/boundless-economics/chapter/other-demand-elasticities/

	prod_id_x	YearWeek	weekly_demand_pct	prod_id_y	discounted_price_pct	discounted_price	cross_elasticity
41408168	21204739	2020-20	0.915792	21090447001	-0.014587	6.08	-62.782623
41408169	21204739	2020-20	0.915792	21092325001	0.028609	7.91	32.011090
41408172	21204739	2020-20	0.915792	21097012001	0.151163	1.98	6.058316
41408173	21204739	2020-20	0.915792	21108053001	-0.203593	3.99	-4.498154
41408177	21204739	2020-20	0.915792	21179969001	0.016293	4.99	56.206728

Figure 2: Cross elasticity table

After computing the complement price and substitute price, our next step is to calculate competitor price. Since we can regard substitutes as competitors for a product, we identify a product's competitor as the one with the largest value of cross-price elasticity. In order to calculate competitor price for each product, we use the discounted price of the product with the largest cross elasticity as the competitor price of the target product.

2.1.5 Seasonality

In terms of seasonality, we notice that our data already included the week index, which can also be used to measure the different time period, and it is even more precise than using seasons. Thus, we decide to use the week number in each year as a "seasonality" measure.

The final complete table after data cleaning and data preparation is shown below:

	prod_id	YearWeek	list_price	weekly_amt	weekly_demand	discounted_price	year	week	discounted_price_pct	weekly_demand_pct	discount_level	substitute_price	complement_price	competitor_price
0	20001892	2017-25	5.0	2235.0	447	5.0	2017	25	NaN	NaN	0.0	NaN	NaN	NaN
1	20001892	2017-26	5.0	8785.0	1757	5.0	2017	26	0.0	2.930649	0.0	7.261495	8.565272	15.28
2	20001892	2017-27	5.0	9285.0	1857	5.0	2017	27	0.0	0.056915	0.0	44.256554	7.445517	15.77
3	20001892	2017-28	5.0	11690.0	2338	5.0	2017	28	0.0	0.259020	0.0	7.942552	38.590053	9.81
4	20001892	2017-29	5.0	10430.0	2086	5.0	2017	29	0.0	-0.107784	0.0	17.812929	8.369198	11.88

Figure 3: Weekly level data with cross elasticity table

2.2 Exploratory Data Analysis

2.2.1 Cumulative Percentage of Total Sales

There are always products in ACSE Supermarkets that customers frequently purchase, which will result in a long tail across items when focusing on cumulative percentage of store sales. The top

12.95% of items account for 90% total sales, and the lowest selling 80.78% of items account for only 5% of total sales.

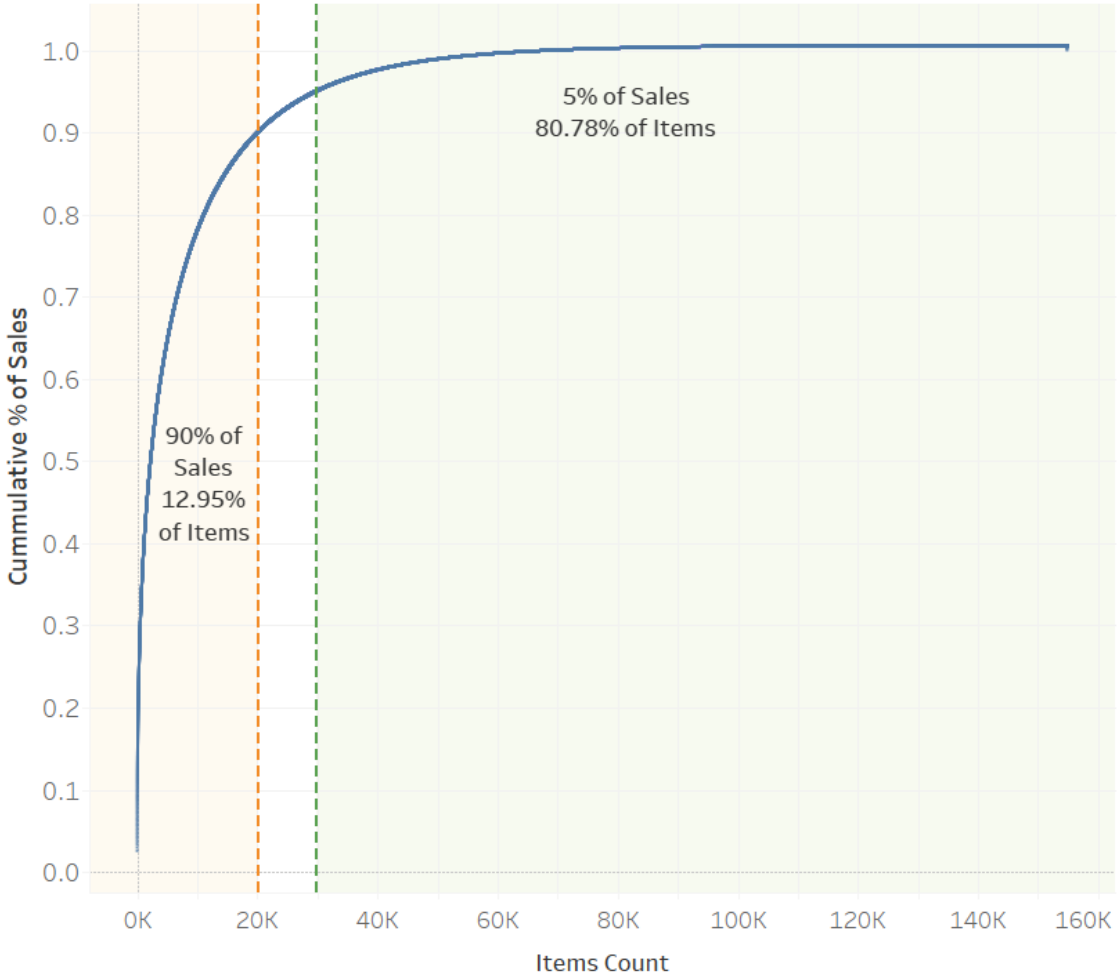
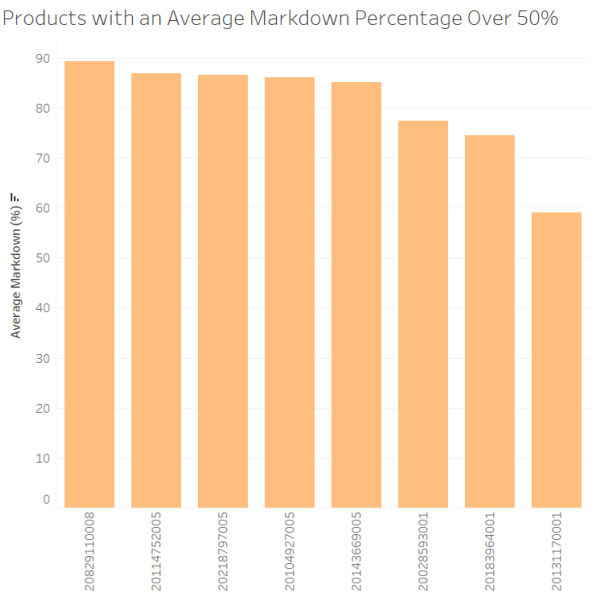


Figure 4: Cumulative percentage of total sales across items

2.2.2 Markdowns

The distribution of the average markdown percent on products ranges from 0 to 89.35%; only 8 products of the 511 had an average markdown percentage over 50%. Understanding markdown percentage levels for individual products is important as customers may recognize if a typically highly marked down product is seeing price increases.



2.2.3 Prices of Substitute/Competitor Products

As demonstrated in the price comparison graph below, on average, target products' substitute/complement products tend to be of a higher price. The median difference in the list price of a target product and the competitor products price is a -2.2, suggesting that list prices of most target products can be decreased without customers switching over to the substitute products.

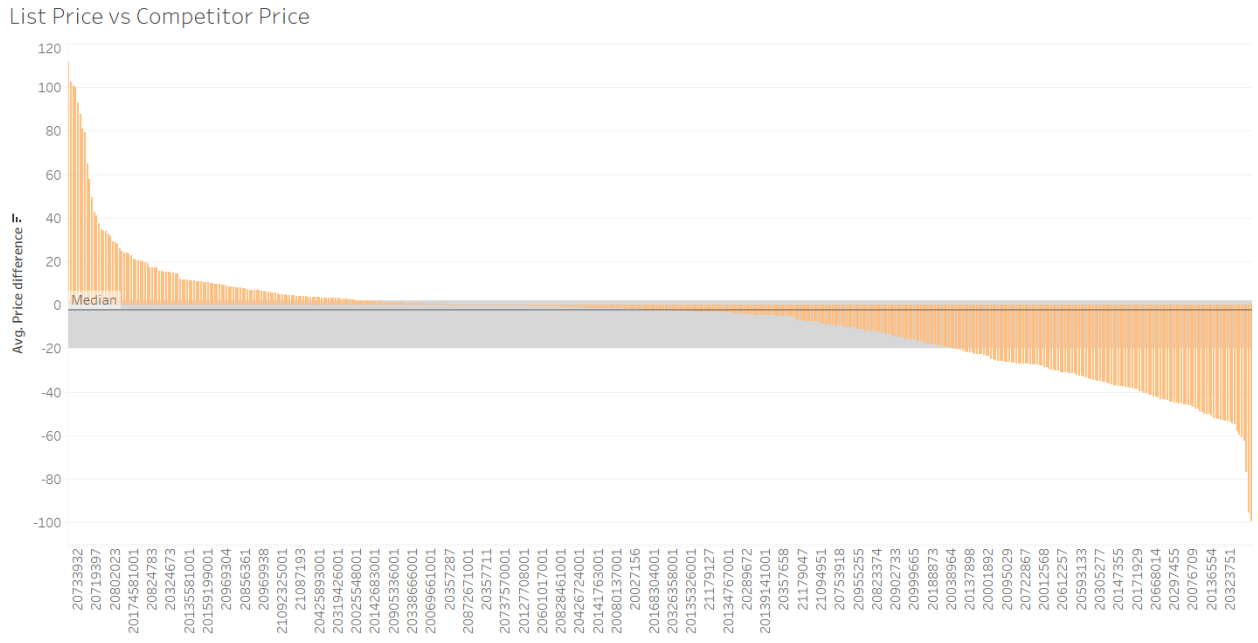


Figure 5: List Price vs. Competitor Price

3. Price Response Function

3.1 Logit Response Function

The causal factors for us to consider in the price response model include price factors (e.g. product discount level, price for substitute/complement products) and untrollable factors (e.g. seasonality). The previous data cleaning and data preparation parts give us most of the factors for modeling.

When optimal prices are needed, the logit response function should be used for this purpose. Before modeling, we transformed the demand by logistic transformation. The demand_transformed is calculated from weekly_demand_max (the maximum weekly demand) for each product as the theoretical maximum demand of this product in any period, using:

$$demand_transformed = log(\frac{weekly_demand}{weekly_demand_max - weekly_demand})$$

After the logistic transformation on the historical demand, we kept other factors with no transformations and defined our Price Response Function as:
demand_transformed ~ discounted_price + substitute_price + complement_price + week + discount_level

The following table shows the result from our Price Response Function, with *prod* as the product ID, and *coef0* to *coef4* as the coefficient of each variable:

	prod	coef0	coef1	coef2	coef3	coef4	intercept
0	20001892	0.000000	0.004537	0.006521	0.000013	0.000000	-0.953165
1	20002646001	0.652361	-0.031779	-0.460871	0.005587	-9.087702	-2.440749
2	20003839001	-0.387083	0.181794	-0.168142	0.000602	-0.503278	1.300225
3	20005739	0.043266	-0.002035	0.001173	-0.006661	0.063773	0.336101
4	20005858	-1.091803	0.007975	0.007134	-0.010503	0.128716	5.240355
...	...	...	...	...	...	...	...
506	21179127	0.456252	0.032552	-0.722807	-0.003424	1.052833	0.052777
507	21184958	0.007147	0.711497	0.426715	-0.005295	-0.002536	-6.388337
508	21189812	-0.335201	0.682139	-0.338870	-0.002441	-0.344683	-0.134511
509	21204386	-0.188538	0.425274	0.348922	-0.021952	0.087895	-1.835372
510	21204739	-0.095426	0.541575	0.072520	-0.021867	-0.074609	-3.102101

Figure 6: Price Response Function Result

3.2 Obtaining the Optimal Price

The price response function can give us a linear relationship between log(demand) and selected variables. In order to investigate EDLP products and less price sensitive products, further work needs to be done to find the optimal price for each product. Theoretically, If we want to adjust list prices to maximize revenue (and ignore incremental cost), and to express it in an equation, it is:

$$max_p\, pd(p)$$

The equation can be solved by taking the derivative of M(p) and setting it equal to 0:

$$M'(p) = pd'(p) + d(p) = d(p)(\frac{pd'(p)}{d(p)} + 1) = d(p)(\epsilon(p) + 1) = 0$$

Therefore, from the above equation, we can see that the revenue-maximizing price p can be derived when price elasticity ($\epsilon(p)$) equals to -1.

For a logit price response function, the formula of price elasticity is:

$$\epsilon(p) = \frac{bp}{1+e^{-(a+bp)}}$$

It is worth noting that (a+bp) can be obtained from the result in the previous step, where we use the five coefficients and the intercept as the exponent of e. Specifically, a is the intercept, b is the coefficient of discounted_price, and we add c, d, e, and f as the coefficients of the rest of the variables.

Instead of directly calculating the optimal p when the elasticity of p equals to -1, we iterated multiple numbers of price as p to calculate the elasticity for each product, and then used the price which makes the elasticity equal to (or extremely close to) -1.

	prod_id	price	elasticity	dist
407	20005858	7.07	-0.984984	0.015016
503	20007535001	3.03	-0.917678	0.082322
1102	20020516001	2.02	-0.982679	0.017321
1415	20026161001	15.15	-0.850682	0.149318
1563	20026703001	63.64	-0.987384	0.012616
...	...	...	...	...
49001	21058519	1.01	-1.100896	0.100896
49426	21087812	26.26	-0.990247	0.009753
49709	21090447001	9.09	-0.990155	0.009845
50103	21097012001	3.03	-0.984295	0.015705
50910	21204386	10.10	-0.965658	0.034342

Figure 7: Optimal price and elasticity result

By comparing the optimal price to the discounted price, we can determine whether the product has a price increase or decrease, we can also compute the percentage change on price using these two numbers, the final result table is shown below:

	prod_id	list_price	discounted_price	price	elasticity	dist	increase_price	price_pct	revenue
67	20602264	6.054309	5.599834	22.22	-0.968544	0.031456	1	2.967975	12596.74
225	20905336001	6.243731	5.907761	14.14	-0.856130	0.143870	1	1.393462	12675.56
69	20612257	2.981271	2.804751	3.03	-1.122114	0.122114	1	0.080310	12900.85
207	20690699001	5.697238	5.385801	12.12	-0.943646	0.056354	1	1.250362	14215.64
12	20078939	3.866028	3.793121	5.05	-0.880521	0.119479	1	0.331358	14236.02
...	...	...	...	...	...	...	...	...	...
20	20121871	17.427722	15.342111	5.05	-0.913799	0.086201	0	-0.670841	117382.70
107	20964482	22.434681	19.557447	10.10	-0.980248	0.019752	0	-0.483573	180490.47
115	20972941	32.411068	25.627573	8.08	-1.022163	0.022163	0	-0.684715	182808.38
90	20812304	39.599841	28.077143	7.07	-0.975434	0.024566	0	-0.748194	203368.55
175	20182566001	6.096739	5.522500	5.05	-1.010535	0.010535	0	-0.085559	237675.80

Figure 8: Optimal price and discounted price

Using the above table, we can distinguish the 50 EDLP products and 100 less price sensitive products as our price change recommendations for ACSE. The detailed product list and explanation is demonstrated in the following part of the report.

4. Price Recommendation

4.1 Products List

Using the analysis and modeling techniques described above, our team identified 50 products that can withstand a price decrease to become EDLP items and 100 items whose prices can be increased to offset the costs. We selected these 150 products out of 234 promising products (all 234 products' predicted elasticity deviates from -1 with 0.15) whose predicted revenue is as high as possible. The product list contains important features of the product, current prices, suggested price, elasticity, the percent increase in price, and the additional revenue it will bring in.

4.1.1 Price Decrease Products

The following 50 products have been identified to be in the ELDP category. The product list below for these products is sorted by ascending additional revenue provided. The range of the price percent changes is from -2% to -84%.

ELDP: Products to Target for Price Decreases							
Product ID	Current List Price	Current Discounted Price	Suggested Price	Product Elasticity	Distribution	Percent Price Decrease	Revenue
20801192	16.56491713	14.48767956	14.14	-0.96516019	0.03483981	-2%	14390.52
20126276	4.449558011	4.336685083	2.02	-0.927213992	0.072786008	-53%	14973.6
20310940001	4.620441989	4.243756906	3.03	-1.070053008	0.070053008	-29%	15869
20020516001	2.204833333	2.151166667	2.02	-0.982678717	0.017321283	-6%	16525.98
20902733	10.1181768	9.050552486	2.02	-0.91322555	0.08677445	-78%	16755.67
20031454001	4.853756906	4.673425414	2.02	-0.919090387	0.080909613	-57%	16856.42
20172914	4.414611111	4.4035	3.03	-0.978582951	0.021417049	-31%	17468.22
20949866001	6.712929936	6.474203822	2.02	-0.967915482	0.032084518	-69%	17770.88
20148677	5.774972376	5.644088398	3.03	-1.068367621	0.068367621	-46%	18149.47
20813628001	5.270388889	5.199666667	2.02	-0.94190843	0.05809157	-61%	18956.51
20318694002	4.542983425	4.293038674	4.04	-1.004950636	0.004950636	-6%	19302.24
20138228001	6.541277778	6.200388889	2.02	-0.959385605	0.040614395	-67%	20962.02
20969304	16.91943503	15.08937853	11.11	-0.984776505	0.015223495	-26%	22490.32
20805201001	6.314206349	5.573333333	2.02	-1.044520675	0.044520675	-64%	25305.67
20310752	8.249889503	7.272486188	2.02	-1.142268986	0.142268986	-72%	25854.2
20969161	7.282272727	6.557329545	6.06	-0.991675147	0.008324853	-8%	26201.24
20840038001	6.425337079	6.206235955	2.02	-1.050764108	0.050764108	-67%	27214.6
20162945001	5.186055556	4.784444444	4.04	-1.126867394	0.126867394	-16%	27587.67
20348977001	4.980977011	4.613678161	1.01	-0.974192562	0.025807438	-78%	28950.2
20907647001	5.863478261	5.563152174	1.01	-0.983542642	0.016457358	-82%	30106.99
20067326001	7.023370166	6.113535912	5.05	-0.939549333	0.060450667	-17%	34932.08
20828461001	4.391049724	4.077016575	2.02	-0.978494987	0.021505013	-50%	39608.35
20520970	11.84055556	10.63844444	3.03	-1.044224927	0.044224927	-72%	40238.65
20826568001	6.698376068	6.293589744	1.01	-0.959444395	0.040555605	-84%	41230.32
20145379001	4.845911602	4.32718232	2.02	-1.084477566	0.084477566	-53%	42631.72
20601020001	5.178381503	4.042080925	3.03	-0.95837341	0.04162659	-25%	44135.98
20081865	9.762707182	9.244640884	2.02	-1.00363927	0.00363927	-78%	44952.13
20852143	9.933149171	8.886298343	4.04	-0.988229005	0.011770995	-55%	45708.22
20973326	13.4986747	10.81566265	3.03	-0.955469427	0.044530573	-72%	47591.91
20974107	26.59126437	21.42942529	4.04	-1.053607944	0.053607944	-81%	47788.03
20289672	23.54994475	20.77524862	8.08	-1.037493985	0.037493985	-61%	49168.41
20974527	20.01692771	15.95560241	3.03	-0.950812641	0.049187359	-81%	58074.19
20821992	19.44287293	17.75933702	5.05	-1.000926424	0.000926424	-72%	62076.36
20660950	28.56729282	24.49093923	9.09	-0.992615287	0.007384713	-63%	64343.56
20085851001	5.499834254	4.640773481	2.02	-1.112162672	0.112162672	-56%	66973.84
20357711	22.4752809	17.7247191	5.05	-0.948559988	0.051440012	-72%	71892.81
20357787	19.7840884	15.40127072	4.04	-0.926270821	0.073729179	-74%	72370.54
20808969	13.71243478	11.5153913	5.05	-1.034118887	0.034118887	-56%	73420.43
20093631	12.87110497	10.9839779	3.03	-0.97776117	0.02223883	-72%	77105.6
20821154	22.90502762	21.00933702	17.17	-1.005390021	0.005390021	-18%	79193.12
20313872001	6.498603352	6.057877095	2.02	-0.968150261	0.031849739	-67%	83075.06
20135377001	4.913093923	4.341657459	3.03	-1.069270486	0.069270486	-30%	92913.98
20974101	15.09550562	12.03157303	5.05	-0.911009677	0.088990323	-58%	101506.5
20720065	23.5039779	20.55248619	15.15	-1.001837305	0.001837305	-26%	106730.7
20007535001	3.618453039	3.320552486	3.03	-0.917677815	0.082322185	-9%	115042.2
20121871	17.42772222	15.34211111	5.05	-0.913798845	0.086201155	-67%	117382.7
20964482	22.43468085	19.55744681	10.1	-0.980248375	0.019751625	-48%	180490.5
20972941	32.41106796	25.62757282	8.08	-1.022163277	0.022163277	-68%	182808.4
20812304	39.59984127	28.07714286	7.07	-0.975433804	0.024566196	-75%	203368.6
20182566001	6.09673913	5.5225	5.05	-1.010534524	0.010534524	-9%	237675.8

Figure 9: Product to target for price decrease

4.1.2 Price Increase Products

The following products have been identified to see price increases in order to fund the ELDP initiative; this list has been sorted in ascending order for additional revenue provided. This selected range of products sees an increase in price from .28% to 1731%.

Products to Target for Price Increases

Product ID	Current List Price	Current Discounted Price	Suggested Price	Product Elasticity	Distribution	Percent Increase	Revenue
20602264	6.054309392	5.599834254	22.22	-0.968544144	0.031455856	297%	12596.74
20905336001	6.243731343	5.907761194	14.14	-0.856130248	0.143869752	139%	12675.56
20612257	2.981270718	2.804751381	3.03	-1.122113677	0.122113677	8%	12900.85
20690699001	5.697237569	5.385801105	12.12	-0.94364562	0.05635438	125%	14215.64
20078939	3.866028369	3.793120567	5.05	-0.880520878	0.119479122	33%	14236.02
20823374	5.559342105	5.070921053	6.06	-0.985168145	0.014831855	20%	14301.69
20117351	6.852154696	5.719944751	13.13	-1.059678283	0.059678283	130%	14369.94
20056675	6.847513812	6.602983425	8.08	-1.081669835	0.081669835	22%	14487.45
20323751	6.828287293	6.539502762	13.13	-0.995529717	0.004470283	101%	14590.36
21050572	3.473163842	3.321864407	5.05	-0.923025375	0.076974625	52%	15128.12
20318915	3.588839779	3.321767956	4.04	-0.975481657	0.024518343	22%	15154.97
20035921	3.880985915	3.806690141	7.07	-0.915326092	0.084673908	86%	15512.96
21048165	6.522647059	5.743176471	10.1	-1.126995635	0.126995635	76%	15843.45
20065036001	3.109723757	2.989281768	3.03	-1.000134168	0.000134168	1%	15926.6
20315960	6.846022099	6.603314917	7.07	-1.080569871	0.080569871	7%	16016.25
20125267	3.865774648	3.791760563	8.08	-1.029638956	0.029638956	113%	16313.28
20095029	8.694869565	6.739043478	33.33	-0.977939251	0.022060749	395%	16393.75
20338666001	7.019909091	6.624636364	7.07	-1.059194036	0.059194036	7%	16592.65
20779176001	4.725944444	4.538611111	21.21	-1.020110841	0.020110841	367%	16710.49
20119813001	4.500165746	4.256187845	6.06	-1.139131958	0.139131958	42%	16715.11
20969938	7.144588235	6.315764706	43.43	-0.998487644	0.001512356	588%	16930.63
20897813	9.091049724	7.773867403	34.34	-1.05792898	0.05792898	342%	17070.05
20963330	5.003543307	4.287480315	7.07	-1.013655682	0.013655682	65%	17470.03
20326678	13.5258011	11.24712707	21.21	-1.14435378	0.14435378	89%	17498.78
20312227	4.746243094	4.220662983	6.06	-0.999599915	0.000400085	44%	17743.65
20771852	2.974033149	2.868066298	3.03	-0.9067582	0.0932418	6%	17888.54
20218303	3.961871345	3.863099415	5.05	-0.967231621	0.032768379	31%	18854.87
20314960	3.651111111	3.377055556	11.11	-1.12140408	0.12140408	229%	19266.53
20601017001	5.939833333	4.937444444	9.09	-1.137297357	0.137297357	84%	19844.42
20600927001	2.628103448	2.395402299	6.06	-1.003289873	0.003289873	153%	20201.82
21030970001	8.37780303	8.091515152	21.21	-1.021683615	0.021683615	162%	20612.5
20057892	6.437458564	5.511823204	9.09	-0.950002942	0.049997058	65%	20868.28
20772671	6.443535912	5.612044199	7.07	-0.954335681	0.045664319	26%	21163.97
20141814001	3.152541436	2.892928177	11.11	-1.055433037	0.055433037	284%	21619.85

20253488001	4.315966851	4.074530387	11.11	-0.899601928	0.100398072	173%	21845.31
20147976	12.68201117	10.54687151	14.14	-0.875399607	0.124600393	34%	22442.61
20183964001	5.25	4.365027624	5.05	-0.91302131	0.08697869	16%	22916.57
20137898	2.236464088	2.02839779	3.03	-1.056103646	0.056103646	49%	23153.85
20600792001	4.833480663	4.684696133	5.05	-1.011204531	0.011204531	8%	23154.46
20127917001	7.200828729	6.70839779	56.57	-1.047144747	0.047144747	743%	23272.41
20166880001	3.418121547	3.084198895	11.11	-1.013333422	0.013333422	260%	23632.73
20115704	13.30690608	12.44961326	41.41	-1.010242559	0.010242559	233%	25835.61
20167017001	3.976740331	3.465248619	6.06	-1.105668495	0.105668495	75%	27921.22
20767998001	6.669392265	6.361491713	24.24	-0.898820181	0.101179819	281%	27937.62
20130270	4.449723757	4.336132597	11.11	-1.122127151	0.122127151	156%	28438.45
20114752005	28.33083799	22.57659218	32.32	-0.991813081	0.008186919	43%	28441.6
20104927005	23.83458564	19.73033149	30.3	-1.004362352	0.004362352	54%	28530.48
20972859	3.675888889	3.400611111	4.04	-1.0468736	0.0468736	19%	30324.9
20732366	6.41961326	5.752265193	13.13	-0.85561785	0.14438215	128%	30476.64
20306054	4.732099448	4.186850829	8.08	-0.978400339	0.021599661	93%	30971.85
21050575	3.481704545	3.331022727	8.08	-1.029053999	0.029053999	143%	31188.24
20821170	12.34342541	11.55364641	30.3	-1.004032015	0.004032015	162%	31673.73
20789931	10.30783333	8.646444444	24.24	-1.001452546	0.001452546	180%	32112.94
20795315001	5.372928177	5.093701657	18.18	-0.934252245	0.065747755	257%	32642.38
20133884001	2.834722222	2.724888889	6.06	-1.00339215	0.00339215	122%	33446.94
20737570001	4.648729282	4.471546961	15.15	-1.094434691	0.094434691	239%	34173.16
20788888	8.84878453	7.391823204	14.14	-1.123839693	0.123839693	91%	34360.57
20377023	13.29038674	12.2061326	29.29	-0.979576164	0.020423836	140%	35847.53
20601014001	4.886234568	4.66882716	5.05	-0.99969647	0.00030353	8%	36658.8
20358106	9.005149254	7.173134328	77.78	-1.01790414	0.01790414	984%	36973.13
20774431	3.763646409	3.379171271	7.07	-0.981560993	0.018439007	109%	37869.05
20296112005	6.367845304	5.247845304	14.14	-0.895399591	0.104600409	169%	39089.05
20325274001	5.981491713	5.469889503	13.13	-0.979690753	0.020309247	140%	41302.09
21204386	6.301343284	6.150895522	10.1	-0.96565769	0.03434231	64%	42581.74
20997902	17.57475138	17.2859116	69.7	-1.072724827	0.072724827	303%	42907.99
20153925	8.93961326	8.073701657	27.27	-0.99285466	0.00714534	238%	51375.34
20069661001	7.659244186	7.055581395	10.1	-0.857674071	0.142325929	43%	51972.75
20503017001	5.101987578	4.898757764	27.27	-0.97052773	0.02947227	457%	53823.72
20426596001	2.642541436	2.43441989	3.03	-0.985555781	0.014444219	24%	55632.69
20049221	9.333093923	8.672044199	24.24	-1.040411012	0.040411012	180%	56143.11
20083454001	2.654254144	2.481546961	6.06	-0.993569468	0.006430532	144%	56758.67
20083526001	4.277237569	3.995027624	13.13	-1.040746884	0.040746884	229%	60987.3
20034947001	6.995222222	6.553888889	24.24	-0.952076407	0.047923593	270%	61882.59
20056190001	5.767277778	5.496	17.17	-1.032740488	0.032740488	212%	63291.31
20067389001	4.983370166	4.489558011	7.07	-1.114969465	0.114969465	57%	65360.31
20814294001	4.977955801	4.767569061	29.29	-0.977902303	0.022097697	514%	73614.86
20425893001	2.627845304	2.412044199	14.14	-1.061527302	0.061527302	486%	74076.24
20172240001	3.808839779	3.521767956	5.05	-1.013074887	0.013074887	43%	74573.67
20639926	6.20839779	5.047790055	18.18	-0.881680765	0.118319235	260%	83723.21
20026161001	4.043555556	3.661444444	15.15	-0.850682206	0.149317794	314%	90562.4
20970981	6.175414365	5.602486188	15.15	-1.000291962	0.000291962	170%	96347.71
20812144001	2.50281768	2.490939227	7.07	-0.953610282	0.046389718	184%	100790.8
20174581001	6.158066298	5.373425414	7.07	-0.985543408	0.014456592	32%	116081.9
20426078001	4.202651934	3.824972376	4.04	-0.949673533	0.050326467	6%	116874.66
21027142001	5.427131783	5.269379845	33.33	-1.059611744	0.059611744	533%	128461.2
20702919	8.163701657	7.448232044	83.84	-0.997690013	0.002309987	1026%	131679.56
21087812	18.61992701	17.63145985	26.26	-0.990246689	0.009753311	49%	133732.83
20070132001	2.08640884	1.887734807	6.06	-1.141196151	0.141196151	221%	137229.47
20426141001	3.384972376	3.06480663	11.11	-0.972489225	0.027510775	263%	137709.47
20128938001	4.026187845	3.315690608	11.11	-1.134562777	0.134562777	235%	144846.19
20159199001	7.485801105	6.042928177	6.06	-0.884630683	0.115369317	0%	153179.59
20425775001	7.994972376	6.671823204	27.27	-1.066065082	0.066065082	309%	158247.25
21097012001	1.975909091	1.735454545	3.03	-0.984294994	0.015705006	75%	184421.67
20974632	13.2060221	11.60022099	13.13	-1.025620847	0.025620847	13%	188120.07
20810558	13.64174603	11.42952381	28.28	-0.93707236	0.06292764	147%	199418.55
20152465001	4.118012821	3.744871795	60.61	-1.010161803	0.010161803	1518%	201221.77
20145621001	3.367624309	3.09198895	5.05	-1.030633218	0.030633218	63%	274934.39
20026703001	3.848729282	3.475635359	63.64	-0.98738437	0.01261563	1731%	285990.32
20080137001	5.290110497	4.74359116	31.31	-1.043071043	0.043071043	560%	422185.04
20049778001	4.903314917	4.37640884	6.06	-1.027923962	0.027923962	38%	485685.92

Figure 10: Product to target for price increase

4.2 Executing Price Changes

A few nuances have to be considered when thinking about executing the price changes mentioned above. Because consumers are very likely to notice large increases in price, our team suggests performing further research on the specific time periods and levels of price increases that should take place for products with over 60% suggested price increases.

Additionally, research suggests that customers should be made aware of the reasons for price increases[4]. It might play to ACSE's benefit to add little tags next to prices with significant increases that explain that these increases are offsetting price decreases in other products. In line with the Harvard article, messaging surrounding price changes should focus on the benefits ACSE's consumers will receive as a result of the EDLP.

5. Expected Changes

After we calculated the optimal price and found the price response function for each product, we used the following function to calculate the demand based on the optimal price:

$$d(p) = \frac{Ce^{-(a+bp)}}{1+e^{-(a+bp)}}$$

Since the dependent variable of the price response function is the demand with logistic transformation, we transformed the result of demands back as the expected demand with the price adjustment. By multiplying the demand and price, we obtained the maximized revenue for each product as the expected revenue. The table below shows the expected changes in demand and revenue.

	prod_id	price	demand	revenue
0	20005858	7.07	454.782106	3215.31
1	20035921	7.07	2194.195434	15512.96
2	20038148	4.04	2658.822952	10741.64
3	20049221	24.24	2316.134882	56143.11
4	20055009	4.04	2429.129896	9813.68
5	20056675	8.08	1793.000754	14487.45
6	20057892	9.09	2295.740043	20868.28
7	20058742	2.02	3639.022951	7350.83
8	20059572	5.05	2450.362711	12374.33
9	20065207	10.10	467.285447	4719.58
10	20069080	1.01	6002.603196	6062.63
11	20076709	6.06	1045.153763	6333.63
12	20078939	5.05	2819.014783	14236.02
13	20081865	2.02	22253.529490	44952.13
14	20091686	2.02	2270.977297	4587.37
15	20093631	3.03	25447.392357	77105.60

Figure 11: Expected changes in demand and revenue

[4] "If You're Going to Raise Prices, Tell Customers Why", hbr.org/2021/06/if-youre-going-to-raise-prices-tell-customers-why

Using the transaction data, we can also calculate the yearly revenue of the products that would have price adjustment in each store. Compared to the yearly revenue of products with price adjustments, we found that the revenue in all the stores would increase, with the maximum increase of 92% in store 1424, and an increase of 51.53% across all stores. The table below shows the top ranked stores by the percentage of revenue increase.

store_id	original_profit	optimal_profit	profit_increase	original_revenue	optimal_revenue	revenue_increase	revenue_increase_pct
1424	512313.91	983822.25	471508.34	2561569.55	4919111.26	2357541.71	0.92
1142	553933.88	906709.52	352775.63	2769669.41	4533547.58	1763878.17	0.64
1007	1951210.24	3073622.89	1122412.66	9756051.18	15368114.47	5612063.29	0.58
1010	1334173.35	2113032.83	778859.47	6670866.76	10565164.13	3894297.37	0.58
1155	975629.15	1544077.54	568448.39	4878145.75	7720387.69	2842241.94	0.58
1194	1592060.44	2494962.39	902901.95	7960302.21	12474811.97	4514509.76	0.57
1095	1163036.89	1810936.76	647899.87	5815184.45	9054683.81	3239499.36	0.56
1212	2502651.72	3901931.25	1399279.53	12513258.59	19509656.24	6996397.65	0.56
1179	604575.67	936253.04	331677.37	3022878.36	4681265.22	1658386.86	0.55
1170	1061847.57	1648612.63	586765.06	5309237.84	8243063.14	2933825.30	0.55
1154	682158.60	1054307.51	372148.91	3410793.02	5271537.57	1860744.55	0.55

Figure 12: Top stores ranked by % increase in revenue

Looking into the increase in demand, we found that the demand in all the stores would increase, with the maximum increase of 35% in store 1208, and an increase of 24.04% across all stores. The table below shows the top ranked stores by the percentage demand increase.

store_id	original_demand	optimal_demand	demand_increase	demand_increase_pct
1208	707928.62	957257.50	249328.88	0.35
1003	927589.13	1233491.41	305902.28	0.33
1142	555182.53	734925.60	179743.07	0.32
1032	1274737.93	1682680.37	407942.44	0.32
1028	1412604.86	1829734.76	417129.90	0.30
1023	626026.64	815675.23	189648.59	0.30
1200	578152.47	748435.79	170283.32	0.29
1064	941207.26	1207099.96	265892.70	0.28
1179	576050.29	732358.07	156307.78	0.27
1082	844694.78	1076430.93	231736.15	0.27
1092	1260327.19	1585126.42	324799.23	0.26

Figure 13: Top stores ranked by % increase in demand

6. Conclusion

Our team's analysis into ACSE Supermarket's product pricing recommendation has resulted in product promotion strategies to increase store revenue. Implementing price elasticity and logit response function provide an extra layer of personalization that will directly speak to products and customers. Our team strongly believes in these recommendations and looks forward to helping with their implementation in the future.