INTRO

Star Technologies Company (STC) is our client and long-time manufacturer of remote controls for televisions and audio systems. As they have the technical expertise, production, and distribution capacity, they are interested in bringing forward an STC tablet for which they would like to rely on quantitative data when developing the product. We are provided with these quantitative survey research results that include the Choice-Based Conjoint (CBC) task and Discrete Choice Experiment (DCE). Our goal is to use Bayesian methods to accurately understand and predict customer preferences to provide STC with viable recommendations on size, capacity, and price regarding the tablet they will go to market with.

EXPLORATORY DATA ANALYSIS

The experiment has 5 factors that are (1) Screen Size, which has 3 levels, 5", 7" and 10", (2) RAM, which has 3 levels, 8GB, 16GB, and 32GB, (3) Processing Power which has 3 levels, 1.5 GHz, 2.0 GHz and 2.5 GHz, (4) Price which also has 3 levels, $199, $299 and $399, and finally, (5) Brand which has 4 levels, STC, Somesong, Pear and Gaggle. When the number of levels under each factor taken into account, there are 324 total number of choices (3*3*3*3*4 = 324). For our analysis, we will be using a Fractional Factorial Design of 108 choices, which is one-third of the total number of choices. The design matrix we will use in our analysis will have 108 rows, aka product design tasks, and 5 variables, which are the 5 factors.

The responses' dataset consists of 424 observations and 55 variables, which represent one survey/experiment question each. Included within the 55 variables are 36 task questions, whereas the remaining questions are related to demographic and geographic information on the respondent.

Most responders live in California, which represents approximately 9% of the responders, followed by responders who live in Florida and Pennsylvania. Arkansas, Delaware, Mississippi, Montana, and New Mexico are the states where only one responder currently lives.

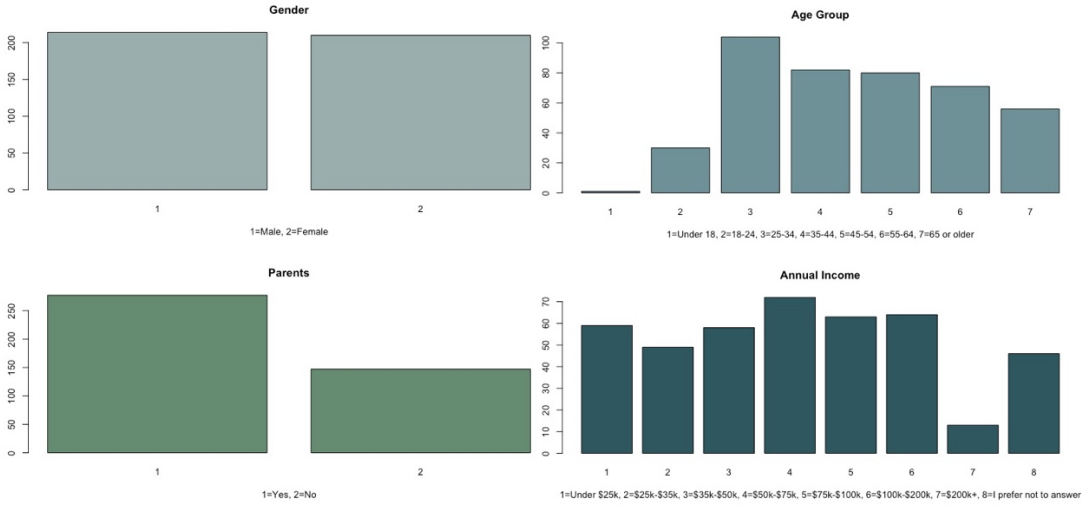

Figure 1: Barplots of demographic question responses

Four bar charts, presented in Figure 1, show additional insight on responses given to the demographics related questions such as age, gender, income, and parenthood. From a total number of observations, 214 have identified as male and 210 identified as female, and 277 as parents, and 147 not as parents. The follow-up questing for parents asking the age of child showed that most respondents have children between the ages of 6 and 12 and younger than 2. In addition, if we look at the bar plots on the right-hand side, we can see that the greatest number of responders are in the 25-34 age group, followed by 35-44 and 45-54. Finally, the annual income that is the most common response is (4) $50,000 - $75,000,

which accounts for 17% of the total respondents' annual income bracket. When we explore the responses given to each 36 DCM Task, we see a pattern that can be observed in every 9 DCM, which occurs 4 times throughout the dataset.

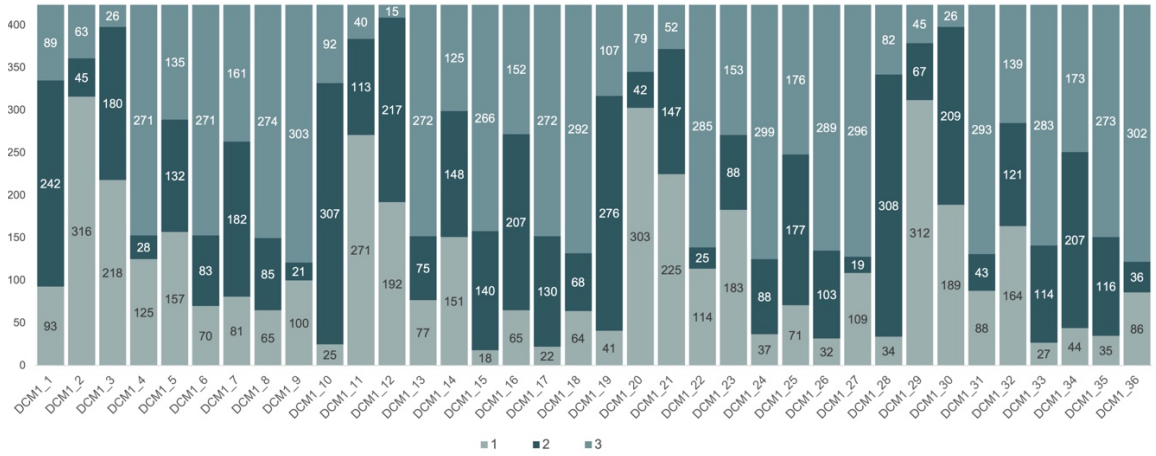

Figure 2: Distribution of chosen options in each DCM task

Also presented in Figure 2, we can see a similar outcome in every +9 of any DCM. For example, if we look at DCM1_4, we can see that majority of the respondents have chosen Option 3, followed by Option 1, yet very few have gone with Option 2. We can see very similar behavior in DCM1_13, DCM1_22, and DCM1_31. This plot clearly shows us that (a) overall, if we look at the sum of each time each option has been chosen, we see that option 3 overall has been picked the most, and (b) there is a similar pattern repeated in every 9 DCM, which gives us 4 buckets overall. There are obvious similarities between these choice sets, and their effect on predictions should be further observed.

Additionally, if we look at some of the tasks, certain choices were very strongly preferred over others. For example, in DMC1_2-Option 1 had been selected by 75% of the respondents. When we look further into the details of that task, we see that it had 7" screen size (medium), 16GB RAM (average), 2.5 GHz processor (high), $199 price (low) and STC brand. If we compare Task 2 with Task 10 where choice #2 was highly popular, which has 5" screen size, 32GB RAM, 2.0 GHz processor, and identical to Task 2, $199 price and STC brand. Simply by looking at this graph and understanding the tasks, we can see that when the price is low and the brand is STC within a choice, it becomes popular.

MODELLING

As previously described our design matrix holds one third of all choice options, which is 324, therefore consists of 108 rows. As a part of the effects coding, we have converted each level under each factor to an integer ranging from -1 to 2 as below:

- Screen: -1=5", 0=7", 1=10"
- Price: -1=$199, 0=$299, 1=$399
- RAM: -1=8GB, 0=16GB, 1=32GB
- Processor: -1=1.5GHz, 0=2.0GHz, 1=2.5GHz
- Brand: -1=STC, 0=Somesong, 1=Pear, 2=Gaggle

With the above predictor variables, the design matrix with effects coding is then used together with all responses in order to run the Hierarchical Bayesian Multinominal Logistic Regressions model, where we will be running 50,000 iterations and ask the model to grab every 5th simulation; thus, we are going to have 10,000 simulations to use in our analysis.

For this analysis, we will be running two separate Hierarchical Bayesian Multinominal Logistic Regressions (HB MNL), one with all the data from all respondents and the second with only the data from respondents who are already STC product owners. Both models will use the Markov Chain Monte Carlo simulation and run with the 'rhierMnlDP' function in 'bayesm' R package.

HB MNL MODEL

We ran the first model using all of the experiment responses Hierarchical Bayesian Multinominal Logistic Regressions, not taking into account any covariation. As already described above, the models will draw 10,000 samples from 50,000 iterations, which will give us 10,000 simulations on each respondent. Below is the MCMC simulation beta draw plots and the distribution plots of some attributes, which are 7-inch and 10-inch screen size, $299 and $399 price, of the respondents that we randomly picked. The goal of looking at these plots is to see whether we can set a burn-in point, which is where we see a stabilization on the beta draws and see where the beta draw value falls on the density chart, essentially indicating preference in case of these 3 random respondents.

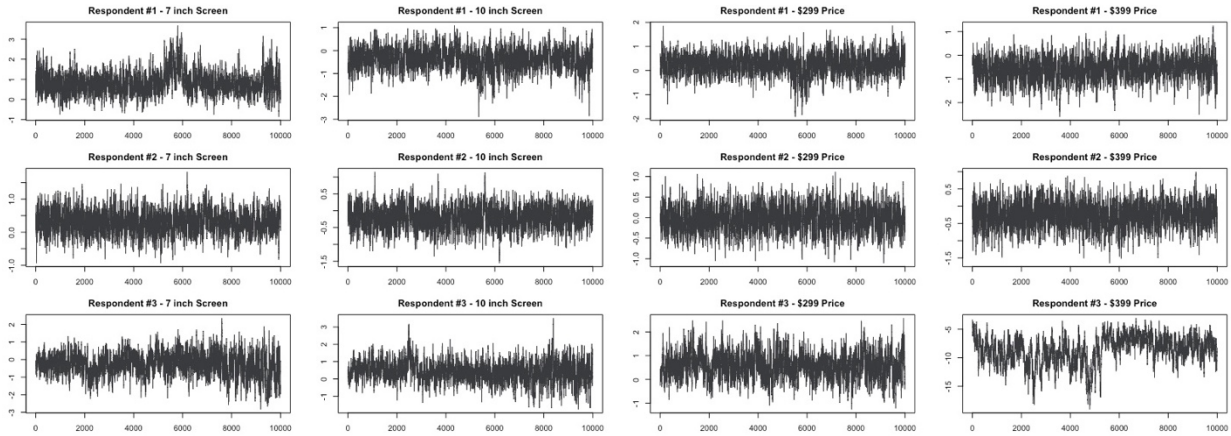

Figure 3: Beta Draws of screen size and prices attributes of respondents 1, 2 and 3

The four plots presented in Figure 3 do not give us an exact burn-in point as we see the draws' beta value does not consistently stabilize in any of the graphs. The only plot we see some stabilization is where we plotted respondent #2 10-inch Screen beta draws, which indicates the burn-in point at around 6200 draws, yet when we compare that burn-in point with the same plot we got for respondent #1 and #3, we see that the 6200 burn-in points do not apply. If we look at the price-related beta draw plots, we can see that even at around 10,000 simulations, the beta value does not stabilize. So, per the above analysis, we fail to identify a burn-in period less than 10,000, and is it likely that in the future, we would need to conduct a 100,000 iterations simulation to establish an approximate burn-in point

Next, we want to have a brief look at the variation of beta means. We use the same attributes and random respondents as we used for the above analysis. Below in Figure 4 presented are the distribution plots.

When we look at the cut-off line, which sits on x=0, and the area under the curve, we can see that respondents 1 and 2 have similar preferences between all three random respondents. When it comes to screen sizes respondent, 1 and 2 preferences differ from respondent 3 significantly, yet when price attributes are concerned, we can see that all respondents like $299 pricing and strongly dislike the $399 pricing, which respondent 3 dislikes significantly as we see the peak beta distribution is on the more negative side than others.

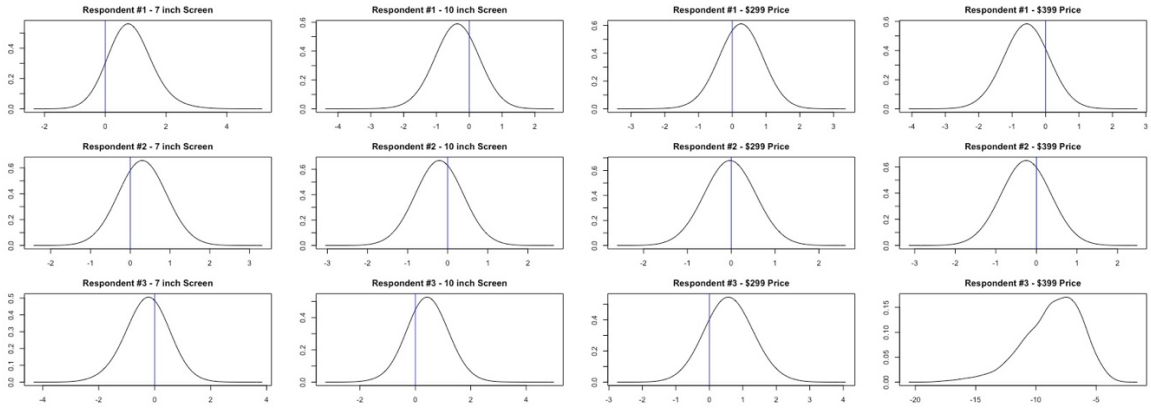

Figure 4: Beta Draws of screen size and prices attributes of respondents 1, 2 and 3

As the final step of this model, we will be looking at the beta means of each attribute with all respondents taken into consideration.

Attribute	*Model 1 - Beta Means*
5-inch	-0.26415226
7-inch	-0.19391782
10-inch	0.45807008
8GB	-0.72425659
16 GB	0.08588558
32 GB	0.63837101
1.5 GHz	-2.292817
2.0 GHz	0.99687813
2.5 GHz	1.29593887
$199	2.52468222
$299	0.29354402
$399	-2.81822624
STC	0.4240882
Somesong	-0.19972281
Pear	0.06941814
Gaggle	-0.29378353
STC by Price	-0.11488519
Somesong by Price	0.0495028
Pear by Price	0.04278469
Gaggle by Price	0.0225977

Table 1: Beta means of each attribute per HB MNL model

The beta means for each attribute give us an insight into the preferences of all 424 respondents. If we start the review of the beta means with the screen size related features, we can see that of the three levels under this factor, which are 5-inch, 7-inch, and 10-inch screens, a great majority of the respondents prefer 10-inch screen size over 5- and 7-inch screens. As the 5- and 7-inch screen sizes got a negative beta mean, we can state that they are not preferred. Continuing with RAM, we see that there is a strong dislike towards 8GB RAM, and respondents would like the RAM to be either 16GB or 32GB, preferably 32GB. A similar pattern is observed when it comes to Processing Power. Respondents highly prefer the highest processing power, which is 2.5 GHz, would also prefer 2.0 GHz, yet strongly dislike the 1.5 GHz option.

We see the highest beta means when it comes to the price attribute. The lowest price option, $199, has a beta mean of positive 2.53, which indicates that the respondent strongly prefers it. On the other hand, the highest price option, $399 has a beta mean of negative (-) 2.82, which is the highest beta mean of all and strongly indicates that respondents are not prefer and likely to go with a $399 tablet options. The high beta means we got off the price attributes suggest that price has a substantial impact on the respondent preference.

HB MNL MODEL with COVARIATE

The second model we run is a variation of the HB MNL model we ran previously, yet in this model, we will have 'previous ownership' of STC product as a covariate. This time we will be drawing delta instead of beta as we want the measure to show us the movement in respondent preferences in relation to previous STC product ownership. Our exploratory analysis shows that 68 out of 424 respondents are previous STC owners, representing approximately 16% of all respondents.

Attribute	*Model 1 - Beta Means*	*Model 2 – Delta Means*
5-inch	-0.26415226	*0.07727559*
7-inch	-0.19391782	*-0.01573741*
10-inch	0.45807008	*-0.06153818*
8GB	-0.72425659	*-0.02170619*
16 GB	0.08588558	*0.04671333*
32 GB	0.63837101	*-0.02500714*
1.5 GHz	-2.292817	*-0.34613506*
2.0 GHz	0.99687813	*0.09311878*
2.5 GHz	1.29593887	*0.25301628*
$199	2.52468222	*0.93141716*
$299	0.29354402	*-0.02379349*
$399	-2.81822624	*-0.90762367*
STC	0.4240882	*-0.69689985*
Somesong	-0.19972281	*-0.29753239*
Pear	0.06941814	*1.11760151*
Gaggle	-0.29378353	*-0.12316927*
STC by Price	-0.11488519	*-0.07565045*
Somesong by Price	0.0495028	*-0.18557753*
Pear by Price	0.04278469	*0.05716803*
Gaggle by Price	0.0225977	*0.20405995*

Table 2: Delta means of HB MNL model with previous STC ownership as covariate

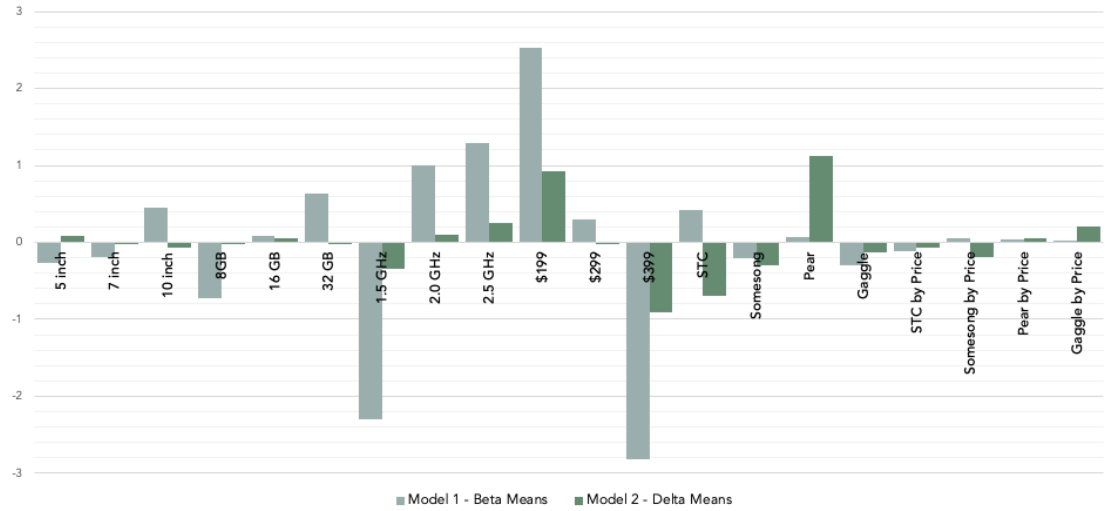

Figure 5: Beta and delta mean comparison

The above table, Table 2, and Figure 5 present the delta means from the HB MNL model with previous ownership as a covariate, together with the beta means from Model 1, the HB MNL model without any covariates.

If we start by reviewing and comparing the delta means for factor levels related to screen size, we can see that in contrary to model 1 beta means, respondents who had previous STC product ownership prefer a smaller screen size of 5-inch and don't want to go with 7- or 10-inch screen sizes. As far as the RAM is concerned, we see that respondents who previously owned the STC product do not prefer the highest RAM, 32GB; ideally, they prefer a 16GB RAM yet are also relatively likely to even go for an 8GB RAM. The

processing power beta and delta means comparison between models 1 and 2 do show similar behavior. While the highest processor of 2.5GHz is the most preferred, we see that means are much smaller, meaning the respondents with previous STC ownership are not likely to feel strongly about the processor being 2.5GHz than the beta means of all respondents.

Even with previous STC ownership, $199 price is preferred over $299 and $399. While previous ownership impacts the $299 price mean to go negative, the $399 mean is -0.908 compared to -2.82, meaning previous ownership does affect the respondent to dislike the high price point less, when though it is still not preferred.

Finally, when we look at the brand-related means from each model, we see that previous ownership results in a drastic shift from STC to Pear product. A previous STC product owner is less likely to go for the STC product than the respondent who doesn't have previous ownership.

MODEL ACCURACY & NEW CASES

As the final step of the analysis, we bring in new cases (extra scenarios) to assess both models' predictive accuracy. We generate a matrix with the respondents' data with 424 rows and one-third of the choice options, 108, which gives us 15,264 rows that we'll be using to assess our model's accuracy. Below are the confusion matrices for both HB MNL (Model 1) and HB MNL with covariate (Model 2) models.

customer choice	1	2	3
1	**3674**	418	213
2	231	**3748**	208
3	299	423	**6050**

customer choice	1	2	3
1	**3647**	470	222
2	253	**3676**	231
3	304	443	**6018**

Table 3: Model 1 Confusion Matrix (left) & Model 2 Confusion Matrix (right)

Per the confusion matrix results, we calculate the Model 1 accuracy as 88% ((3674+3748+6050)/15264 = 0.88) and Model 2 accuracy as 87% ((3647+3676+6018)/15264 = 0.87), with multi-class accuracy of 91% and 90%, respectively. We accepted both models as they are above our minimum accuracy threshold, which is 80%. When we bring new cases to our model, we get the below accuracy of predicting each task and option.

	1	2	3	1	2	3
DCM1_1	85	252	87	2.34%	95.98%	1.68%
DCM1_2	344	30	50	**99.38%**	0.53%	0.08%
DCM1_3	242	162	20	75.90%	24.10%	0.00%
DCM1_4	109	13	302	9.25%	0.48%	90.26%
DCM1_5	191	104	129	65.86%	18.66%	15.48%
DCM1_6	69	57	298	0.76%	5.33%	93.91%
DCM1_7	75	192	157	15.54%	42.78%	41.68%
DCM1_8	63	65	296	0.62%	3.87%	95.52%
DCM1_9	101	9	314	5.59%	0.05%	94.36%
DCM1_10	30	306	88	0.44%	**99.09%**	0.47%
DCM1_11	305	93	26	97.02%	2.86%	0.12%
DCM1_12	197	216	11	36.46%	63.54%	0.00%
DCM1_13	57	67	300	7.16%	1.47%	91.37%
DCM1_14	176	127	121	41.26%	46.05%	12.69%
DCM1_15	19	115	290	0.53%	14.51%	84.97%
DCM1_16	44	222	158	8.67%	67.46%	23.87%
DCM1_17	17	117	290	0.57%	9.97%	89.47%
DCM1_18	54	64	306	5.45%	0.14%	94.42%

	1	2	3	1	2	3
DCM1_19	39	280	105	1.28%	96.79%	1.93%
DCM1_20	331	28	65	98.85%	0.98%	0.17%
DCM1_21	261	113	50	63.13%	36.87%	0.00%
DCM1_22	111	11	302	3.95%	0.34%	95.71%
DCM1_23	208	55	161	48.62%	22.98%	28.40%
DCM1_24	32	74	318	0.31%	3.66%	96.03%
DCM1_25	53	189	182	10.10%	42.04%	47.85%
DCM1_26	35	80	309	0.35%	3.34%	96.31%
DCM1_27	94	10	320	3.24%	0.04%	96.71%
DCM1_28	35	311	78	0.70%	98.32%	0.99%
DCM1_29	330	53	41	98.03%	1.81%	0.16%
DCM1_30	226	176	22	47.90%	52.09%	0.00%
DCM1_31	79	31	314	5.91%	0.97%	93.13%
DCM1_32	185	96	143	44.09%	39.17%	16.74%
DCM1_33	21	91	312	0.45%	9.87%	89.68%
DCM1_34	29	225	170	7.80%	61.57%	30.63%
DCM1_35	25	100	299	0.41%	7.31%	92.28%
DCM1_36	67	26	331	3.88%	0.10%	96.02%

Table 4: Predictive accuracy of each option under each task

Table 4 shows that Task 2-Option 1 and Task 10-Option 2 were the ones with the highest accuracy. When we look at Task 2 Option 1, we see that the choices are a 7-inch screen, 16GB RAM, 2.5 Processor, $199 Price, and an STC brand. On the other hand, when we review Task 10 Option 2, we see that it has 5-inch screen size, 32GB RAM, 2.0 GHz Processor, $199 Price, and STC brand. This shows us that our model was able to accurately predict the tasks with STC brand options.

Finally, we will look at the prediction accuracy from the respondent angle. When we calculate the accuracy based on the individual models that is ran per respondent. The worst performing individual models, of which there are 16 with accuracy less than %60, are generally of the responses given by male respondents, are in the 25-34 age group, and have an annual income less than $50,000. These are the respondent's demographic characteristics that should be kept in mind in the future experiments as these participants can give the responses that decrease the model accuracy.

RECOMMENDATION

We recommend two types of tablet models for STC to go to market with through our HB MNL models, the generic and with previous ownership covariate and analysis of the model results.

The first tablet model will reflect the preferences of customers that we got through HB MNL model 1. We know that new customers of STC prefer a tablet with a big screen, high RAM, moderate/high processor, and prefer low price yet are also willing to pay a price that is more in the middle of the price range. With that, we recommend that Tablet 1 has a 10-inch screen size, 32GB RAM, 2.5 GHz Processor, and will be sold at $299. Per Model 1 results, we determined that new customers are more likely to prefer STC products over other brands, want all the 'high' specifications at a very low price point.

The second tablet model we recommend is more targeted towards returning STC customers. From the results of Model 2, we know that customers who already own STC products like the screen size to be more on the smaller size, RAM and Processor to be within the mid-range, and price to be relatively low. So our recommendation is for STC to go with a tablet with a 5-inch screen size, 16GB RAM, 2.0 Processor, and at 199$. With a smaller screen size and moderate RAM and processor, we think it is realistic to price the table at $199, whereas with big screen size and high RAM, Tablet Model 1 should be more in the moderate price range, which is $299.

As a part of the product development and marketing process, STC should be mindful that Pear products are a direct competitor, and people who previously owned an STC product prefer to go with the Pear brand. Therefore, it is crucial that these tablets should be marketed against Pear products.