Conjoint II

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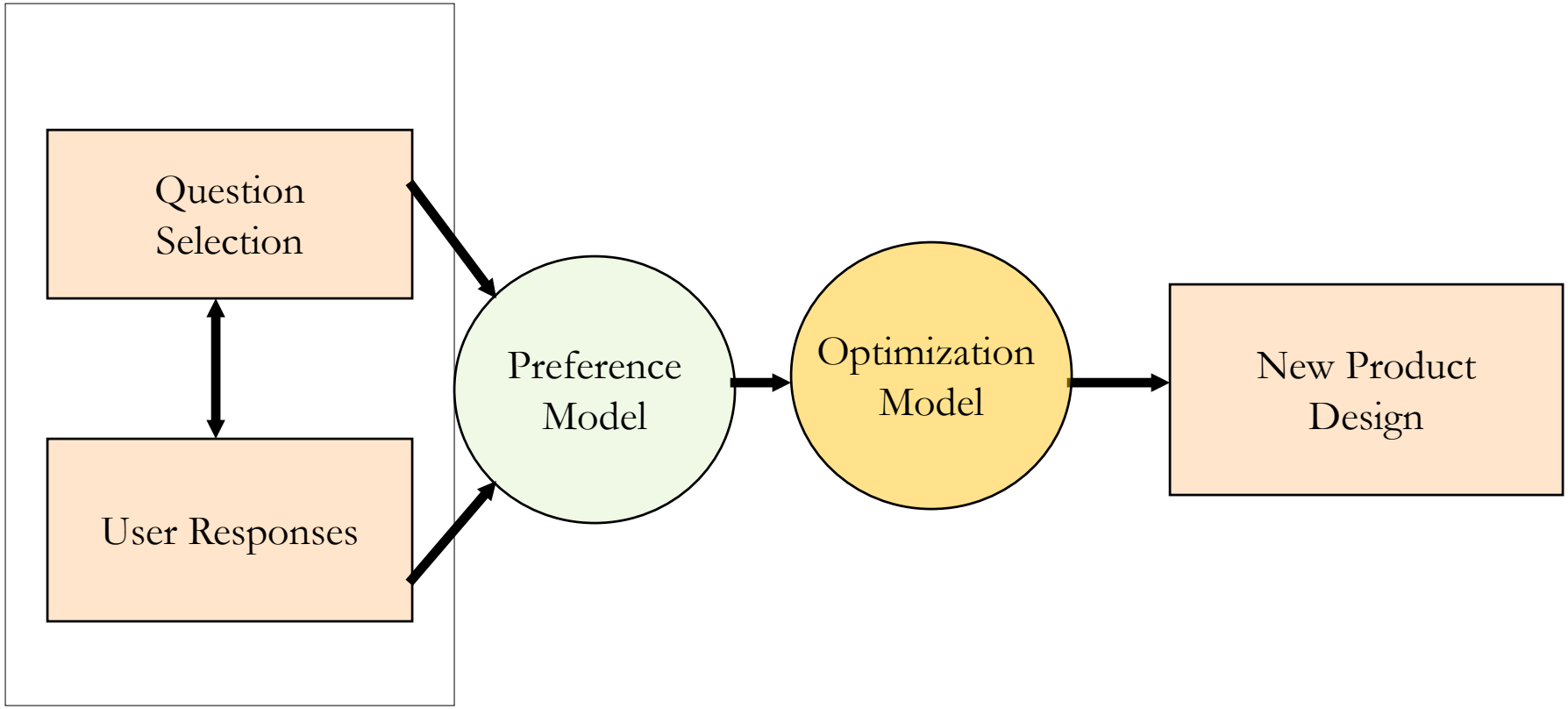
Conjoint Summary



Uses

- Conjoint allows us to predict how product functionality is related to market outcomes
- Conjoint is widely used for
  - Product Line design
  - Demand estimation
  - Optimal pricing
  - Benefit Segmentation

Product Line Optimization via Conjoint

- Suppose a firm is interested in designing an optimal product line of 3 products
- Conducted conjoint analysis to determine how different product features contribute to overall utility
- The firm's management is deciding among 6 product concepts from which it needs to select 3 that are optimal
- Products differ in their profit margin/unit

Product Line Optimization

- 10 Consumers compare new products to a status quo product in terms of overall utility

			Utilities			
Status-Quo	Product 1	Product 2	Product 3	Product 4	Product 5	Product 6
55	47	56	27	61	39	42
62	55	72	55	70	71	79
71	63	70	60	80	79	60
47	55	43	61	60	50	40
90	95	48	91	50	71	80
70	62	81	60	47	61	82
63	58	71	60	69	42	55
59	47	62	53	48	79	71
81	83	80	77	82	71	90
77	66	78	67	79	32	60

- Product margins of 6 products: (8,7,8,6,9,7)

Consumer Choice Process

- Consumers compare the offered products in the line with the status-quo product
- Consumers choose the product that gives highest utility
  - Choose the status quo if it gives higher utility than any offered in the line
- Consumers choose at most one product

Consumer Choice Process

- Consumers choose the product with the highest utility among all available products

	Offered Products						
	Product 1	Product 2	Product 3	Product 4	Product 5	Product 6	
	1	1	0	0	1	0	
Utilities for Available Products							
Status-Quo	Product 1	Product 2	Product 3	Product 4	Product 5	Product 6	Max Utility
55	47	56	0	0	39	0	56
62	55	72	0	0	71	0	72
71	63	70	0	0	79	0	79
47	55	43	0	0	50	0	55
90	95	48	0	0	71	0	95
70	62	81	0	0	61	0	81
63	58	71	0	0	42	0	71
59	47	62	0	0	79	0	79
81	83	80	0	0	71	0	83
77	66	78	0	0	32	0	78

Firm Profits

- The profit to the firm is the sum of the profits from each consumer

Profits from Each Customer						
Product 1	Product 2	Product 3	Product 4	Product 5	Product 6	Max Profit
0	7	0	0	0	0	7
0	7	0	0	0	0	7
0	0	0	0	9	0	9
8	0	0	0	0	0	8
8	0	0	0	0	0	8
0	7	0	0	0	0	7
0	7	0	0	0	0	7
0	0	0	0	9	0	9
8	0	0	0	0	0	8
0	7	0	0	0	0	7

Firm Problem

- Objective: Maximize total profitability (i.e., the sum of the profits from each customer)
- Decision Variables: Whether or not to offer a product (binary variables)
- Solution is a vector of length 6, e.g., (1,1, 0,0,0,1)
- Constraints
  - Only 3 or less products to select in the product line
  - Consumer chooses at most one product, the one that gives the highest utility

Product Line Optimization

- We can use genetic algorithms to solve this optimization problem
- R has the GA package that allows this.
- See the associated rmd file for the solution to this problem

Additional Readings and Links

- Louviere, Hensher and Swait, (2000) *Stated Choice Methods: Analysis and Application*, Cambridge University Press
- Rao, Vithala R. (2014) *Applied Conjoint Analysis*, Springer-Verlag, Berlin Heidelberg

- Sawtooth Software

Choice Based Conjoint (CBC)

A Choice-Based Conjoint Study on Tablets

- When choosing a tablet:
  - How do consumers trade-off between the tablet attributes/features?
  - How much are consumers willing to pay for:
    - One brand relative to another?
    - A product feature (7hrs vs. 9hrs battery)?
- Can we predict the market share for a new tablet?

Tablet Conjoint Study Design

Attribute	Levels
Brand	iPad, Galaxy, Kindle, Surface, Nexus
Screen size in inch	7, 8, 9, 10
Hard drive in GB	16, 32, 64, 128
RAM size in GB	1, 2, 4
Battery life in hours	7, 8, 9
Price in US $	169, 199, 299, 399, 499

A tablet can be described by picking one level from each attribute

Example of a Conjoint Choice Task

Which tablet would you choose?

Brand	iPad	Microsoft Surface	nexus
Screen size	9 inch	10 inch	9 inch
Hard drive	64 gb	128 gb	32 gb
RAM size	4 gb	4 gb	2 gb
Battery life	8 h	7 h	9 h
Price	$399	$399	$199
Alternative	1	2	3

Each consumer was presented 15 choice tasks

Excerpt from the Conjoint Data

```
# loading data
data <- read.csv(file = "conjoint_tablet_data.csv")
```

There are 137 consumers in dataset

ConsumerId	ChoiceSetId	AlternativeIdInSet	Choice	Brand	Size	Storage	Ram	Battery	Price
1	1	1	1	iPad	sz7inch	st32gb	r4gb	b7h	499
1	1	2	0	Surface	sz10inch	st64gb	r2gb	b9h	399
1	1	3	0	Kindle	sz9inch	st16gb	r2gb	b8h	499
1	2	1	1	iPad	sz8inch	st32gb	r1gb	b8h	399
1	2	2	0	Surface	sz10inch	st128gb	r4gb	b7h	299
1	2	3	0	Nexus	sz7inch	st64gb	r1gb	b9h	199

Data Source: Courtesy SawtoothSoftware.com

MNL Model

- Consumer has a utility for each alternative
- Utility is a function of product attributes
  - It is a measure of tablet attractiveness
- Faced with a choice set, the consumer selects the tablet that has the maximum utility

Every Attribute Level has a Sub-Utility (Part-Worth)

- For example, each brand is worth
  - Galaxy: β_{Gal}
  - iPad: β_{iPad}
  - Kindle: β_{Kind}
  - Surface: β_{Surf}
  - Nexus: 0 (reference value)

- The betas (β) are parameters to be estimated from the data

Consumer Utility for a Tablet

$V_j=\beta_{iPad}iPad_j+\beta_{Gal}Gal_j+\beta_{Kind}Kind_j+\beta_{Surf}Surf_j$ ← Brand value

$+ \beta_{10"}10inch_j+\beta_{9"}9inch_j+\beta_{8"}8inch_j$ ← Screen size value

$+ \beta_{128gb}hd128_j+\beta_{64gb}hd64_j+\beta_{32gb}hd32_j$ ← Hard drive value

$+ \beta_{ram4}ram4gb_j+\beta_{ram2g}ram2gb_j$ ← RAM value

$+ \beta_{batt9}batt9hrs_j+\beta_{batt8}batt8hrs_j$ ← Battery life value

$+ \beta_{price}Price_j$ ← Price value

Except Price, all the variables are binary (0/1) variables to indicate the attribute levels of tablet j

Utility of Tablet 1 in Choice Task Example

Brand	iPad	β_{iPad}
Screen size	**9 inch**	$\beta_{9"}$
Hard drive	**64 gb**	β_{64gb}
RAM size	**4 gb**	β_{ram4}
Battery life	**8 h**	β_{batt8}
Price	**$399**	β_{price}**$399**

$$V_1=\beta_{iPad}+\beta_{9"}+\beta_{64gb}+\beta_{ram4}+\beta_{batt8}+\beta_{price}\$399$$

Utility of Tablet 2 in Choice Task Example

Brand	Microsoft Surface	β_{iSurf}
Screen size	**10 inch**	$\beta_{10"}$
Hard drive	**128 gb**	β_{128gb}
RAM size	**4 gb**	β_{ram4}
Battery life	**7 h**	β_{batt7}
Price	**$399**	$\beta_{price}\$399$

$$V_2=\beta_{iSurf}+\beta_{10"}+\beta_{128gb}+\beta_{ram4}+\beta_{batt7}+\beta_{price}\$399$$

Choice Probabilities

$$p_1 = \frac{\exp(V_1)}{\exp(V_1) + \exp(V_2) + \exp(V_3)}$$

$$p_2 = \frac{\exp(V_2)}{\exp(V_1) + \exp(V_2) + \exp(V_3)}$$

$$p_3 = \frac{\exp(V_3)}{\exp(V_1) + \exp(V_2) + \exp(V_3)}$$

$$0 \leq p_j \leq 1, \forall\ j$$

$$p_1 + p_2 + p_3 = 1$$

Estimation Results

```
model <- mlogit(Choice~0+Brand+Size+Storage+Ram+Battery+Price,data=mdata)
summary(model)$CoefTable
```

	Estimate	Std. Error	t-value	Pr(>|t|)
BrandGalaxy	0.3378857	0.0925056	3.652596	0.0002596
BrandiPad	0.9780287	0.0937336	10.434136	0.0000000
BrandKindle	0.2630105	0.0996254	2.639995	0.0082907
BrandSurface	0.1450365	0.0938521	1.545373	0.1222560
Sizesz10inch	0.3240632	0.0841953	3.848949	0.0001186
Sizesz8inch	0.1890775	0.0829232	2.280151	0.0225987
Sizesz9inch	0.4355415	0.0808408	5.387644	0.0000001
Storagest128gb	0.5897703	0.0870533	6.774822	0.0000000
Storagest32gb	0.2168719	0.0829213	2.615395	0.0089124
Storagest64gb	0.5782183	0.0808259	7.153877	0.0000000
Ramr2gb	0.3189348	0.0672579	4.741970	0.0000021
Ramr4gb	0.6357438	0.0645225	9.853053	0.0000000
Batteryb8h	0.1299599	0.0651501	1.994777	0.0460672
Batteryb9h	0.1253824	0.0650588	1.927216	0.0539528
Price	-0.0050888	0.0002752	-18.488626	0.0000000

Tablet Conjoint (sub) Utilities (β Parameters Estimates)

Attributes	Levels	Utilities
Brand	Galaxy	0.33788568
	iPad	0.97802873
	Kindle	0.26301055
	Surface	0.1450365
	Nexus	0
Screen Size	10 inch	0.32406323
	9 inch	0.43554151
	8 inch	0.18907747
	7 inch	0
Hard Drive	128 gb	0.58977033
	64 gb	0.57821825
	32 gb	0.21687192
	16 gb	0
RAM	4 gb	0.63574383
	2 gb	0.31893478
	1 gb	0
Battery	9h	0.12538242
	8h	0.12995991
	7h	0
Price		-0.0050888

- Reference levels are marked in grey

Model Fit

```
model.constrained <- mlogit(Choice~0+Brand,data=mdata)
lrtest(model,model.constrained)
```

```
## Likelihood ratio test
##
## Model 1: Choice ~ 0 + Brand + Size + Storage + Ram + Battery + Price
## Model 2: Choice ~ 0 + Brand
##    #Df  LogLik  Df  Chisq Pr(>Chisq)
## 1  15 -1938.9
## 2   4 -2218.0 -11 558.29  < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Predicted Market Share

Suppose these are the three tablets in the market:

ConsumerId	ChoiceSetId	AlternativeIdInSet	Choice	Brand	Size	Storage	Ram	Battery	Price
1	1	1	1	iPad	sz7inch	st32gb	r4gb	b7h	499
1	1	2	0	Surface	sz10inch	st64gb	r2gb	b9h	399
1	1	3	0	Kindle	sz9inch	st16gb	r2gb	b8h	499

```
kable(head(predict(model,data),1))
```

	alternative 1	alternative 2	alternative 3
Predicted share	0.3717263	0.4405521	0.1877216

Hit Rate: Choice Prediction Accuracy

Confusion Matrix and Statistics

	Reference		
Prediction	1	2	3
1	362	158	130
2	164	449	149
3	136	160	347
Tot	662	767	626

Total number of observations is 2055 (=15 tasks*137 consumers)

Hit Rate=(362+449+347)/2055
=56.4%

vs. 33.3% random prediction

Conjoint Simulator

- The impact of a 2GB RAM upgrade on Galaxy mkt-share

Hypothetical market scenario

Brand	Size	Storage	Ram	Battery	Price	Predicted.Share
iPad	sz7inch	st64gb	r2gb	b8h	399	0.3423928
Galaxy	sz10inch	st32gb	r2gb	b7h	299	0.2540301
Surface	sz10inch	st64gb	r1gb	b7h	399	0.1313854
Kindle	sz7inch	st32gb	r1gb	b9h	169	0.2721917

Suppose Galaxy improves its RAM by 2 GB

Updated

Brand	Size	Storage	Ram	Battery	Price	Predicted.Share
iPad	sz7inch	st64gb	r2gb	b8h	399	0.3127768
Galaxy	sz10inch	st32gb	r4gb	b7h	299	0.3185544
Surface	sz10inch	st64gb	r1gb	b7h	399	0.1200209
Kindle	sz7inch	st32gb	r1gb	b9h	169	0.2486479

Utility Exchange Rate

- The price coefficient indicates that a $1 increase in price leads to a utility decrease by 0.005088 “utiles”

- Thus each “utile” is worth $196.54 (=$1/0.005088)

What is the Brand Value of iPad Relative to Galaxy?

$$\beta_{iPad} - \beta_{Galaxy} \approx 0.6401$$

iPad Value=
0.6401*$196.54 = $125.80

An average consumer would be indifferent between getting a Galaxy tablet vs. paying $125.80 more and getting an iPad.

Similar techniques are often used in litigation, e.g., Samsung vs. Apple: http://www.greenbookblog.org/2014/05/01/how-apple-samsung-and-conjoint-came-together/

```
# brand equity - dollar value of an upgrade from Galaxy to iPad
-(coef(model)['BrandiPad']-coef(model)['BrandGalaxy']) / coef(model)['Price']
```

```
## BrandiPad
##  125.7944
```

Willingness to Pay for an Attribute Upgrade

$$\beta_{4gbRAM} \approx 0.6357$$
$$\beta_{1gbRAM} = 0$$

An average consumer would be willing to pay up to $124.94 to upgrade from 1gb to 4gb RAM, holding all other attributes fixed

4GB Ram Value =0.6357*$196.54
= $124.94

```
# dollar value of an upgrade from 1gb to 4gb ram
-coef(model)['Ramr4gb'] / coef(model)['Price']
```

```
##  Ramr4gb
## 124.9299
```

Conclusion

- Conjoint is the most popular marketing analytics tool in the industry
- Conjoint is of different types
  - Ratings based – Easy to perform, but does not mimic actual choice conditions
  - Choice Based Conjoint:
    - Most used in the industry
    - Can incorporate no choice alternatives to better capture demand