Estimating Consumer Demand for Hedonic Portfolio Products:

A Bayesian Analysis using Scanner-Panel Data of Music CD Stores

by

Yuji Nakayama, Tomonori Ishigaki and Nagateru Araki

College of Economics,
Osaka Prefecture University, JAPAN

The Spotlight Presentation

What are "Hedonic Portfolio Products"‘

- Most products have hedonic and utilitarian attributes.
  - *Hedonic Products* (e.g. movies, fashionable clothes)
  - *Utilitarian Products* (e.g. personal computers, desks & chairs)
- The Characteristics of Hedonic Products:
  - People repeatedly buy products in the category they prefer.
  - But, it is rare that they purchase the same product twice.
- Thus, many hedonic products are purchased as part of a collection.
- Such products are categorized as ***hedonic portfolio products***.
  - A typical example is music CD.

Data

- Scanner Panel Data from music CD stores in Japan
  - Place: 3 Stores in the Tokyo Area and 2 Stores in the Osaka Area
  - Period: Nov 1, 2002 --- Dec 21, 2003
- The distinguishing feature of our data
  - It contains the ID number of customers who purchase a specific music CD title.

Sales of All Stores

Genre	Total Sales (Yen)	Percentage
Japanese Pop	161,247,136	41.8%
Pop, Rock, Blues	113,011,812	29.3%
Dance, Soul, Hip Hop	58,711,011	15.2%
Classic	4,821,240	1.2%
Others (inc. Jazz)	48,376,879	12.5%
Total	386,168,078	100.0%

Purchase History of A Consumer

- This consumer purchased only CDs in genre of Pop, Rock and Blues.

id	year	month	J-Pop	Pop	Dance	Classic	Others
y9K++yl54/g/cF3Pf2LF9A=	2002	11	0	3	0	0	0
y9K++yl54/g/cF3Pf2LF9A=	2002	12	0	3	0	0	0
y9K++yl54/g/cF3Pf2LF9A=	2003	1	0	2	0	0	0
y9K++yl54/g/cF3Pf2LF9A=	2003	5	0	1	0	0	0
y9K++yl54/g/cF3Pf2LF9A=	2003	6	0	1	0	0	0
y9K++yl54/g/cF3Pf2LF9A=	2003	7	0	1	0	0	0
y9K++yl54/g/cF3Pf2LF9A=	2003	8	0	1	0	0	0

Purchase History of Another Consumer

- This consumer purchased not only Dance music CDs but also CDs in genre of J-Pop and Others.

id	year	month	J-Pop	Pop	Dance	Classic	Others
y9K++yl54/iSRQGW49jKzQ	2002	12	1	0	11	0	1
y9K++yl54/iSRQGW49jKzQ	2003	2	2	0	3	0	0
y9K++yl54/iSRQGW49jKzQ	2003	3	0	0	2	0	0
y9K++yl54/iSRQGW49jKzQ	2003	4	0	0	2	0	0
y9K++yl54/iSRQGW49jKzQ	2003	6	1	0	1	0	0
y9K++yl54/iSRQGW49jKzQ	2003	7	1	0	0	0	1
y9K++yl54/iSRQGW49jKzQ	2003	8	1	0	0	0	1
y9K++yl54/iSRQGW49jKzQ	2003	11	2	0	1	0	1
y9K++yl54/iSRQGW49jKzQ	2003	12	1	0	1	0	0

Model

- A consumer maximizes his/her utility given the budget constraint:

$$\max_x U(x) \quad s.t. \quad p'x = E$$

- Kuhn-Tucker Conditions for Optimization

$$\partial U / \partial x_j - \lambda p_j = 0 \qquad \text{if } x_j^* > 0$$

$$\partial U / \partial x_j - \lambda p_j < 0 \qquad \text{if } x_j^* = 0$$

The Random Utility Approach

- Following Kim, Allenby and Rossi (2002) *Marketing Science*, we assume that
  - In the utility function, there are components that the consumer is aware of but are not observable to researchers.
- Thus, using the purchase history of the consumers and KT conditions, we can constitute the likelihood function, if we specify the functional form of the utility.

$$U^h\left(x^h\right)=\sum_{j=1}^{5}\left[\psi_j^h\left(x_j^h+1\right)^{\alpha_j}\exp\left(\varepsilon_j^h\right)\right]$$

The Bayesian Approach

- We assume that the parameters of the utility have the prior distributions.
- For estimation, we use the package *bayesm* and run MCMC.
- In the Discussion and Exhibition Forum, we present our estimates and discuss their implications.
- Then, based on the estimated parameters, we will consider the stock variety and promotion strategy of the retailers to maintain both profitability and customer satisfaction.

The Discussion and Exhibition Forum

Model

- A consumer maximizes his/her utility given the budget constraint:

$$\max_{x^h} U^h\left(x^h\right)\ \ s.t.\ \ p'x^h=E^h$$

$$U^h\left(x^h\right)=\sum_{j=1}^{5}\left[\psi_j^h\left(x_j^h+1\right)^{\alpha_j}\exp\left(\varepsilon_j^h\right)\right]$$

- Kuhn-Tucker Conditions for Optimization

$$\partial U^h/\partial x_j^h-\lambda p_j=0 \qquad \text{if}\quad x_j^{h*}>0$$

$$\partial U^h/\partial x_j^h-\lambda p_j<0 \qquad \text{if}\quad x_j^{h*}=0$$

Prior Distributions

$$\partial U^h / \partial x_j^h = \alpha_j \psi_j^h \left(x_j^h + 1\right)^{\alpha_j - 1} \times \exp\left(\varepsilon_j^h\right)$$

$$\beta_j^h = \ln\left(\alpha_j \psi_j^h\right) \quad \left(\beta_1^h = 0 \ \text{ for identification}\right)$$

$$\beta^h = \left(\beta_2^h, \ldots, \beta_5^h\right)' \sim N\left(\bar{\beta}, V_\beta\right)$$

$$V_\beta \sim IW\left(\nu, V\right) \qquad \nu = 7, \ V = 7 \times diag\left(4\right)$$

$$\bar{\beta} \sim N\left(0, a^{-1} V_\beta\right) \qquad a = 0.01$$

$$\delta_j = \alpha_j - 1 \sim U\left[-1, 0\right]$$

Estimation

- We use *bayesm* and a hybrid MCMC algorithm programmed by Prof. Rossi.
- Burn-in: first 5000 draws
- Last 10,000 draws (thin rate 10) used for estimation.

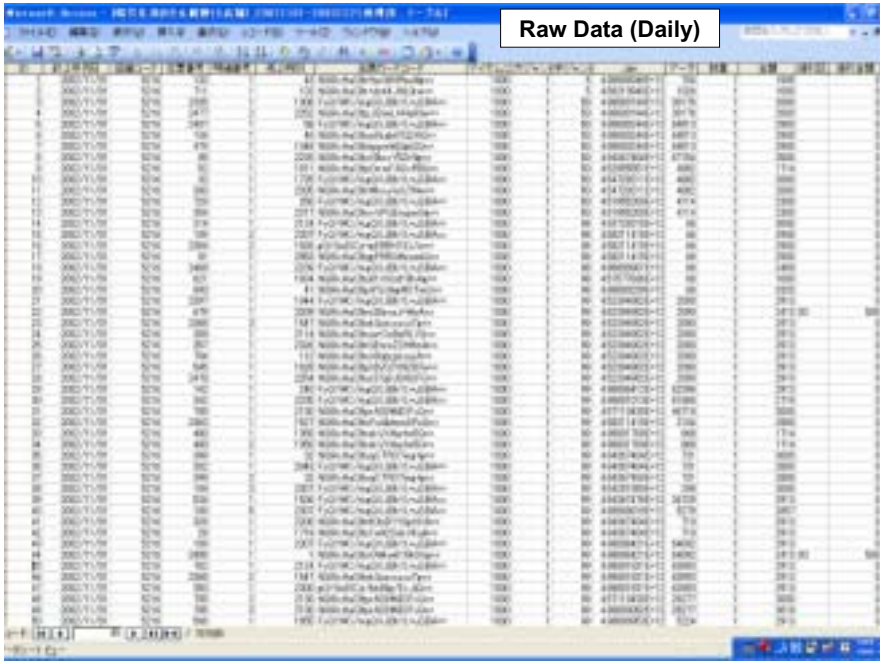
$$\beta^h \left| \delta, X^h, P^h, \bar{\beta}, V_\beta \right.$$ RW step size:0.75

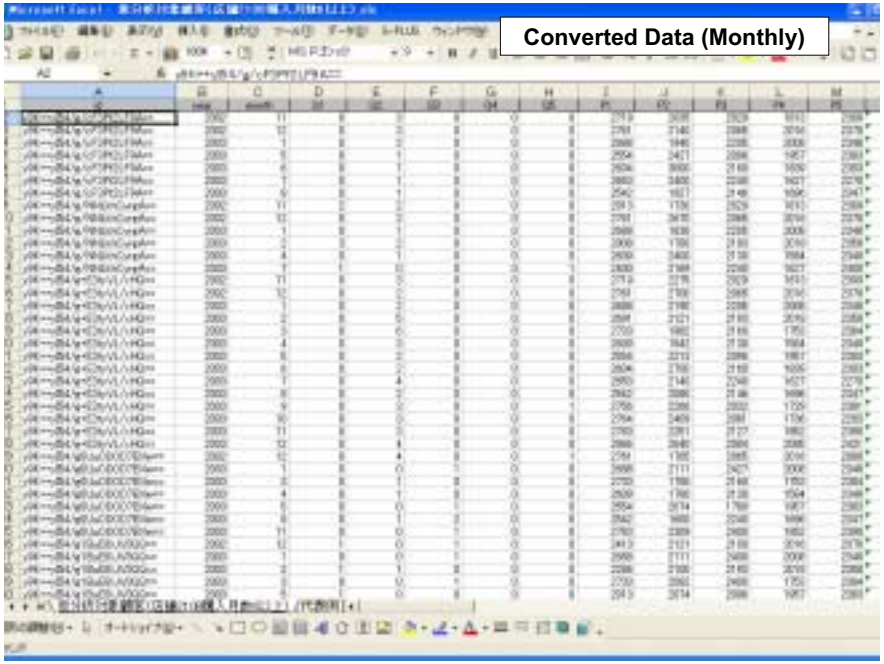
$$\delta \left| \left\{\beta^h\right\}, X, P \right.$$ RW step size:0.1 (changed)

$$\bar{\beta}, V_\beta \left| \left\{\beta^h\right\} \right.$$

Data

- Scanner Panel Data from music CD stores in Japan (Period: Nov 1, 2002 --- Dec 21, 2003)
- Before estimation, we did the following:
  - convert daily raw data into monthly data,
  - select two stores (one store in the Tokyo Area and the other store in the Osaka Area),
  - select customers who visit the Tokyo/ Osaka store more than 5 times.
    - Tokyo Store: 384 Customers with 2827 purchase occasions
    - Osaka Store: 183 Customers with 1342 purchase occasions





Purchase Quantity in a Month

Tokyo Store

Purchase quantity	Frequency	%
1	1483	52.46%
2	715	25.29%
3	344	12.17%
4	151	5.34%
5	57	2.02%
6	30	1.06%
7	20	.71%
8	8	.28%
9	7	.25%
10	5	.18%
11	3	.11%
12	1	.04%
13	2	.07%
14	0	.00%
15	1	.04%
Total	2827	100.00%

Osaka Store

Purchase quantity	Frequency	%
1	644	47.99%
2	357	26.60%
3	169	12.59%
4	80	5.96%
5	37	2.76%
6	23	1.71%
7	6	0.45%
8	6	0.45%
9	7	0.52%
10	4	0.30%
11	3	0.22%
12	2	0.15%
13	3	0.22%
14	1	0.07%
Total	1342	100.00%

Frequency of corner and interior solutions

Tokyo Store

	Purchase incidence	Corner solution	Interior solution
Japanese Pop	982	588	394
Pop, Rock, Blues	1319	852	467
Dance, Soul, Hip Hop	872	503	369
Classic	56	25	31
Others (inc. Jazz)	401	160	241
Total	2827	2128	699

Osaka Store

	Purchase incidence	Corner solution	Interior solution
Japanese Pop	519	335	184
Pop, Rock, Blues	596	365	231
Dance, Soul, Hip Hop	412	214	198
Classic	10	5	5
Others (inc. Jazz)	195	83	112
Total	1342	1002	340

The Monthly Number of Genres Purchased

Tokyo Store

No. Genres Purchased	Frequency	%
1	2128	75.3%
2	601	21.3%
3	92	3.3%
4	6	0.2%
5	0	0.0%
Total	2827	100.0%

Osaka Store

No. Genres Purchased	Frequency	%
1	1002	74.7%
2	292	21.8%
3	46	3.4%
4	2	0.1%
5	0	0.0%
Total	1342	100.0%

Parameter estimates (common to each customer)

Tokyo Store

	betabar		delta	
Genre	mean	sd	mean	sd
Japanese Pop	0.00		-0.38	0.05
Pop, Rock, Blues	0.18	0.11	-0.57	0.05
Dance, Soul, Hip Hop	-0.56	0.12	-0.53	0.06
Classic	-4.18	0.42	-0.48	0.14
Others (inc. Jazz)	-0.86	0.09	-0.40	0.06

Covariance Matrix

Genre	mean	sd	mean	sd	mean	sd	mean	sd
Pop, Rock, Blues	2.71	0.31						
Dance, Soul, Hip Hop	1.08	0.26	3.25	0.40				
Classic	0.81	0.38	0.21	0.56	4.00	1.10		
Others (inc. Jazz)	1.10	0.20	1.45	0.23	1.15	0.42	1.46	0.20

Parameter estimates (common to each customer)

Osaka Store

	betabar		delta	
Genre	mean	sd	mean	sd
Japanese Pop	0.00		-0.30	0.07
Pop, Rock, Blues	0.06	0.16	-0.60	0.07
Dance, Soul, Hip Hop	-0.55	0.17	-0.60	0.07
Classic	-4.36	0.60	-0.26	0.20
Others (inc. Jazz)	-1.04	0.16	-0.43	0.08

Covariance Matrix

Genre	mean	sd	mean	sd	mean	sd	mean	sd
Pop, Rock, Blues	3.35	0.54						
Dance, Soul, Hip Hop	1.64	0.43	3.52	0.61				
Classic	2.44	0.77	1.85	0.69	4.86	1.49		
Others (inc. Jazz)	1.76	0.40	1.93	0.39	2.46	0.63	2.38	0.45

Conversion Formula

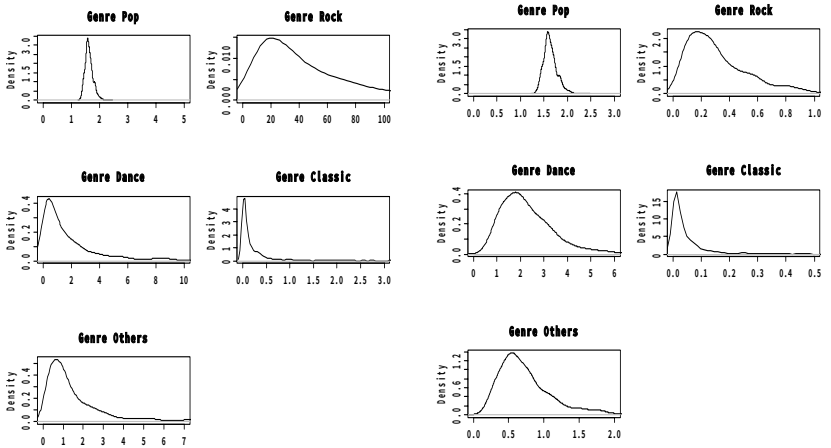
$$\{\delta_j\}\ \{\beta_j^h\} \Rightarrow \{\alpha_j\}\ \{\psi_j^h\}$$

$$\alpha_j = \delta_j + 1, \qquad j = 1,2,...,5$$

$$\psi_1^h = \frac{1}{\alpha_1}, \qquad h = 1,2,...,H \quad (\beta_1^h = 0)$$

$$\psi_j^h = \frac{\exp(\beta_j^h)}{\alpha_j}, \qquad j = 2,...,5, \quad h = 1,2,...,H$$

Posterior Distribution of $\{\psi_j^h\}$



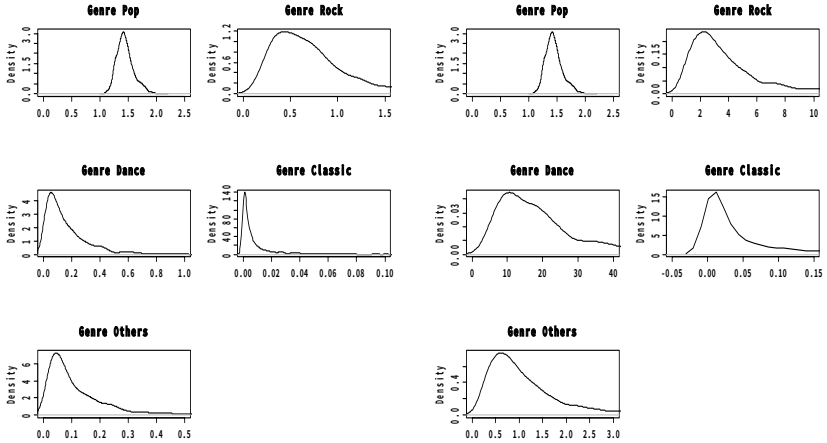
Customer No.1 of **Tokyo Store**

(9K++yI54/g/cF3Pf2LF9A==)

Customer No.276 of **Tokyo Store**

(9K++yI54/iSRQGW49jKzQ==)

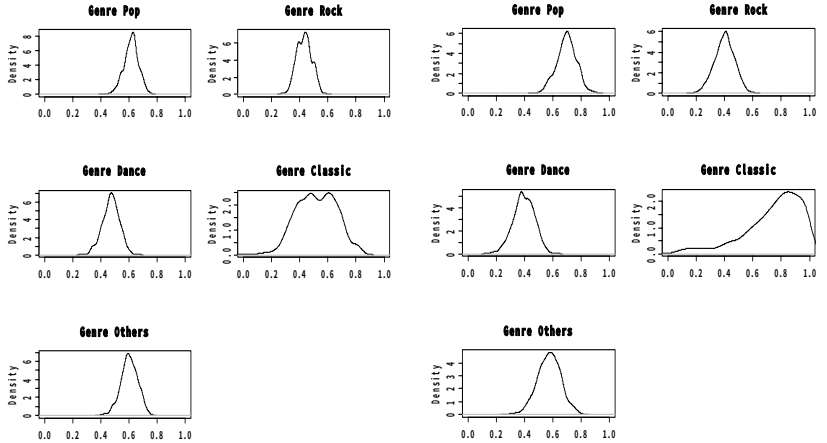
Posterior Distribution of $\{\psi_j^h\}$



Customer No.1 of **Osaka Store**
(KsYHh+I2ARa/nG+yw7w0yQ==)

Customer No.4 of **Osaka Store**
(KsYHh+I2ARa36qjs+IYLUA==)

Posterior Distribution of $\{\alpha_j\}$



Tokyo Store

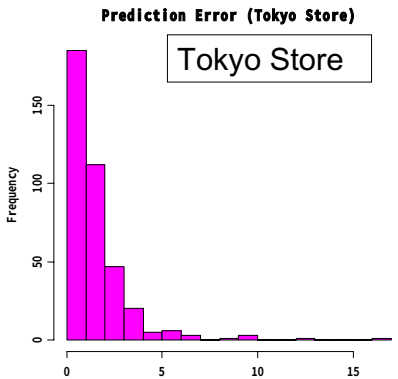
Osaka Store

Histogram of Prediction Error

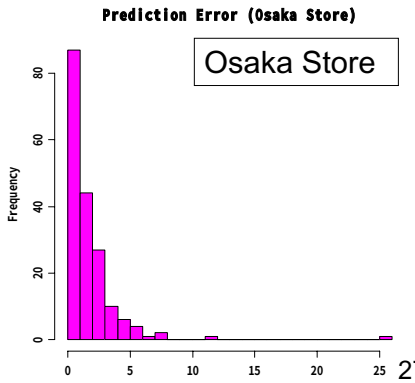
$$(\text{P.E.})^h = \frac{1}{T^h}\sum_{t=1}^{T^h}\sum_{j=1}^{5}\left(x_{jt}^h - x_{jt}^{h*}\right)^2$$

Demand estimated by using **constrOptim** under Posterior Distribution

Actual demand



Tokyo Store



Osaka Store

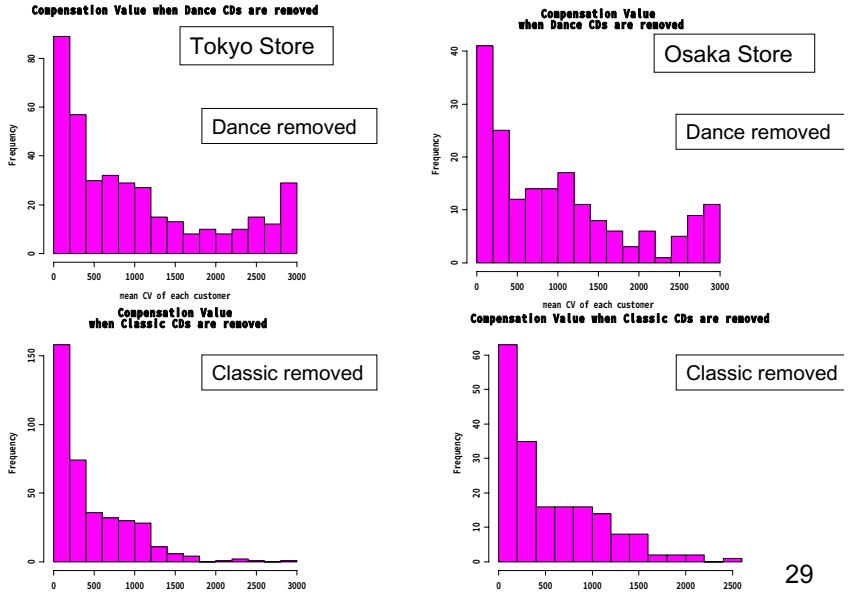
A Plan to change the stock variety

- Each store plans to change its stock variety and to present coupon to each customer.
  - delete shelves of Dance/ Classic CDs.
  - decide the value of coupon to maintain the level of each customer's utility before changing the stock variety. (To solve the following problem, we used R routine **constrOptim**.)

$$\max_{x^h} U^h\left(x^h\right) \;\; s.t. \;\; p'x^h = E^h + CV^h, \;\; x_i^h = 0$$

  - set the upper-limit of the coupon value at 3000 yen (Some customers' utility will be decreased.)

Histogram of Average Coupon Value for each Customer



The Value of Coupon needed for the Deletion of a Genre

- Tokyo Store
  - Dance CDs Total 390,458 yen, Average 1,017 yen
  - Classic CDs Total 182,690 yen, Average 476 yen
- Osaka Store
  - Dance CDs Total 187,273 yen, Average 1023 yen
  - Classic CDs Total 103,362 yen, Average 565 yen

- Which genre the stores should delete depends on how much sales from the rest of the genres increase

Future Research Agenda

- In this research, we estimated the model using the data from each store separately.
- In the future, we consider to estimate a modified model using multiple stores data simultaneously.

- E-mail address

nakayama
ishigaki
araki
@eco.osakafu-u.ac.jp