A Structural Analysis of Detailing, Publicity and Correlated Learning: The Case of Statins

Hyunwoo Lim & Andrew Ching
Rotman School of Management
University of Toronto

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Motivation

Introduction  Data  Model  Results  Conclusion

Number of prescriptions (Millions)

Mevacor  Pravachol  Zocor  Lipitor  Crestor

1st Trial  Q2/2003
Correlated Learning

Introduction  Data  Model  Results  Conclusion

Drug A

LDL

?
Correlated Learning

Introduction  Data  Model  Results  Conclusion

Drug A

Clinical Trial (Drug A)

LDL
Correlated Learning

Introduction  Data  Model  Results  Conclusion
Research Objectives

- Develop a demand model with correlated learning across brands within a category
- Quantify the extent of correlated learning using data on market shares and quality signals (landmark clinical trials)
  - Quantify the late mover advantages
- Taking the presence of switching costs into consideration by employing switching rate data
Quarterly Canadian data for each statin between Q2 1993 and Q4 2004 from IMS Canada

- Prescription volume, Detailing

Quarterly data on switching between Q2 1993 and Q4 2004 from Ontario Health Insurance Program (OHIP)

- % of statin users who switch from a given statin to another statin (2.10% on average) → Switching costs exist.
It is very difficult for physicians to learn about drugs’ efficacy in heart disease risks from patient’s feedback.

Collect 12 landmark clinical trials reporting the efficacy of statins in reducing heart disease risks between 1993 and 2004.

The number of patients consists of 2,000 to 10,000 and the follow-up period ranges from 2 to 6 years.

They provide observable signals (to researchers) on how efficient a statin is in reducing heart disease risks.
2,754 articles mentioning “statin” from “Canadian Accessible Sources” in Factiva between year 1986 and 2004

Classify articles along three dimensions

1. Lowering cholesterol levels (short-term efficacy)
2. Reducing heart disease risks (long-term efficacy)
3. Side effects

Try to overcome the ambiguity of single dimensional coding scheme

Details are provided in Ching, Clark, Horstmann and Lim (2012)
Decision Process of Existing Patient

Keep Taking a Statin

Decide to Switch

Stay with Statin j

Quit Taking a Statin

Statin 1

Statin j-1

Statin j+1

Statin J
Efficacies of Statins

- $q^c_j$ denotes the true efficacy in lowering cholesterol levels of drug $j$
  - The efficacy in lowering cholesterol levels is known to physicians
  - A meta-analysis provides such information

- $q^h_j$ denotes the true efficacy in reducing heart disease risks of drug $j$
  - The efficacy in reducing heart disease is uncertain to physicians
  - Physicians learn about this efficacy from landmark clinical trials
Let $q^h_j$ be the true efficacy in reducing heart disease risks of drug $j$

$$q^h_j = q^c_j \cdot \beta_j,$$

where $q^c_j$ is the efficacy in lowering cholesterol levels and $\beta_j$ is the “efficiency ratio”.
Initial prior beliefs on “efficiency ratio” are constructed as follows (before any landmark trials are available)

\[
\begin{pmatrix}
\beta_1 \\
\beta_2
\end{pmatrix}_{t=0} \sim N\left(\begin{pmatrix}
\beta \\
\beta
\end{pmatrix}, \sigma_\beta^2 \begin{pmatrix}
1 & \rho_0 \\
\rho_0 & 1
\end{pmatrix}\right),
\]

where \(\underline{\beta}\) is the mean initial prior belief about the efficiency ratio of each statin.
Let $\beta_j$ be the true mean level of the efficiency ratio for drug $j$. A noisy but unbiased observable signal from clinical trial $l$ for drug $j$ is

$$\tilde{\beta}_{jl} = \beta_j + \zeta_l$$

where $\zeta_l \sim \mathcal{N}(0, \sigma^2_\zeta/N_l)$ and $N_l$ denotes the number of patients who participate in landmark clinical trial $l$. 
Assume that a physician learns about clinical trial \( l \) for drug 1 at time \( t \). Her posterior belief on the efficiency ratio of drug 2 is

\[
\beta_{2t+1} = \beta_{2t} + \frac{\pi_t}{\sigma_{\beta 2t}^2 + \sigma_{\zeta 1l}^2} (\tilde{\beta}_1 l - \beta_{1t})
\]

where \( \pi_t \) is the covariance in prior beliefs about “efficiency ratio” of drug 1 and 2 at time \( t \).

Her posterior variance on the efficiency ratio of drug 2 is

\[
\sigma_{\beta 2t+1}^2 = \sigma_{\beta 2t}^2 - \frac{\pi_t^2}{\sigma_{\beta 2t}^2 + \sigma_{\zeta 1l}^2}
\]
The probability that a physician will learn the most updated clinical information about drug $j$ at time $t$ is

$$P_{info}(detail_{jt}, PUB_{jt}) = \frac{\exp(\alpha_0 + \alpha_d \cdot detail_{jt} + \alpha_p \cdot PUB_{jt})}{1 + \exp(\alpha_0 + \alpha_d \cdot detail_{jt} + \alpha_p \cdot PUB_{jt})}$$

where $detail_{jt}$ is detailing spending for drug $j$ at time $t$; $PUB_{jt}$ denotes a vector of three dimensional ($lc$, $rh$ and $se$) brand specific publicity variables for drug $j$ at time $t$. 
If there are $n_t$ clinical trials up to time $t$, theoretically there will be $2^{n_t}$ types of physicians at time $t$. ($n_t = \sum_{j=1}^{J} n_{jt}$)

To simplify the model, I assume that if a physician learns about a clinical trial for drug $j$ at time $t$, she will learn about all the published clinical trials for drug $j$ prior to time $t$.

Then, the number of physician types reduces to $(n_{1t} + 1) \cdot (n_{2t} + 1) \cdots (n_{Jt} + 1)$ under this assumption where $n_{jt}$ denotes the number of clinical trials for drug $j$ up to time $t$. 
Let patient $i$’s utility of consuming statin $j$ at time $t$ be

$$U_{ijt} = \omega \cdot q_{j}^{h} + b_{j} + \epsilon_{ijt},$$

where $q_{j}^{h}$ denotes drug $j$’s efficacy in reducing heart disease risks; $b_{j}$ captures time-invariant brand specific preference.

Physician $k$’s expected utility of prescribing drug $j$ to patient $i$ at time $t$ becomes

$$E[U_{ijt}^{k}|I^{k}(t)] = \omega \cdot E[q_{j}^{h}|I^{k}(t)] + \kappa_{d} \cdot STK_{\text{detail}}_{jt} + b_{j} + \epsilon_{ijt},$$

where $STK_{\text{detail}}_{jt}$ is a persuasive detailing goodwill stock for drug $j$ at time $t$. 
The total demand for drug $j$ at time $t$ is expressed as follows.

$$d_{jt} = \hat{d}_{jt}^1 + \hat{d}_{jt}^2 + \hat{d}_{jt}^3 + e_{jt}$$

where $\hat{d}_{jt}^1$, $\hat{d}_{jt}^2$, $\hat{d}_{jt}^3$ are estimated demand for drug $j$ at time $t$ from “new patients”, “switchers” and “retainers”, respectively; $e_{jt}$ is a measurement error.

Estimate the model using Maximum Likelihood.
**Identification**

**Correlated Learning**

- Sales changes after a clinical trial is released identify correlated learning parameters.

**Informative Detailing**

- Variations in sales and detailing before and after each clinical trial release identify the informative effects.
## Result Tables(1)

### Introduction Data Model

<table>
<thead>
<tr>
<th>Learning Parameters</th>
<th>Estimates</th>
<th>S.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>β (Initial Prior Belief on Efficiency Raito)</td>
<td>0.1132</td>
<td>0.0596</td>
</tr>
<tr>
<td>σ_β^2 (Initial Prior Variance on Efficiency Raito)</td>
<td>1.0000</td>
<td></td>
</tr>
<tr>
<td>σ_ς^2 (Signal Variance from 1,000 Patients)</td>
<td><strong>6.0353</strong></td>
<td>0.9996</td>
</tr>
<tr>
<td>ρ_0 (Correlation Term in Initial Prior)</td>
<td><strong>0.6578</strong></td>
<td>0.2634</td>
</tr>
</tbody>
</table>

### Statin Choice Stage, Utility Parameters

<table>
<thead>
<tr>
<th>Statin Choice Stage, Utility Parameters</th>
<th>Estimates</th>
<th>S.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>α_0 (Constant)</td>
<td><strong>-8.0521</strong></td>
<td>0.9993</td>
</tr>
<tr>
<td>α_d (Informative Detailing)</td>
<td><strong>3.4070</strong></td>
<td>1.0096</td>
</tr>
<tr>
<td>α_{lc} (Brand Specific Publicity in Lowering Cholesterol Levels)</td>
<td>0.3661</td>
<td>0.2702</td>
</tr>
<tr>
<td>α_{rh} (Brand Specific Publicity in Reducing Heart Disease Risks)</td>
<td><strong>0.3514</strong></td>
<td>1.0335</td>
</tr>
<tr>
<td>α_{se} (Brand Specific Publicity in Side Effects)</td>
<td>-0.0184</td>
<td>1.0018</td>
</tr>
<tr>
<td>ω (Coefficient of Perceived Quality)</td>
<td>1.1112</td>
<td>0.6330</td>
</tr>
<tr>
<td>κ_d (Persuasive Detailing)</td>
<td><strong>0.0120</strong></td>
<td>0.0042</td>
</tr>
</tbody>
</table>

### Brand Dummies

<table>
<thead>
<tr>
<th>Brand Dummies</th>
<th>Estimates</th>
<th>S.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pravachol</td>
<td><strong>0.8696</strong></td>
<td>0.3887</td>
</tr>
<tr>
<td>Zocor</td>
<td><strong>0.9702</strong></td>
<td>0.3859</td>
</tr>
<tr>
<td>Lipitor</td>
<td><strong>1.0990</strong></td>
<td>0.5409</td>
</tr>
<tr>
<td>Crestor</td>
<td>0.2380</td>
<td>0.7339</td>
</tr>
</tbody>
</table>

| Log Likelihood                                           | -2064.56 |

Estimates shown in bold are significant at 5% level.
## Results

### Adoption Decision Stage Parameters

<table>
<thead>
<tr>
<th>Parameter Description</th>
<th>Estimates</th>
<th>S.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha^s_0$ (Market Expansion Stage Constant)</td>
<td>-5.2073</td>
<td>0.2441</td>
</tr>
<tr>
<td>$\alpha^s_c$ (Clinical Trial * Aggregate Detailing Stock)</td>
<td>0.0111</td>
<td>0.0085</td>
</tr>
<tr>
<td>$\alpha^s_d$ (Aggregate Detailing Stock)</td>
<td>0.0082</td>
<td>0.0011</td>
</tr>
<tr>
<td>$\alpha^s_{lc}$ (General Publicity Stock in Lowering Cholesterol Levels)</td>
<td>0.3661</td>
<td>0.2702</td>
</tr>
<tr>
<td>$\alpha^s_{rh}$ (General Publicity Stock in Reducing Heart Disease Risks)</td>
<td>0.3514</td>
<td>1.0335</td>
</tr>
<tr>
<td>$\alpha^s_{se}$ (General Publicity Stock in Side Effects)</td>
<td>-0.0184</td>
<td>1.0018</td>
</tr>
</tbody>
</table>

### Additional Parameters

<table>
<thead>
<tr>
<th>Parameter Description</th>
<th>Estimates</th>
<th>S.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\delta^s_d$ (Carryover Rate of Detailing in Adoption Decision)</td>
<td>0.9720</td>
<td>0.0060</td>
</tr>
<tr>
<td>$\delta^s_p$ (Carryover Rate of Publicity in Adoption Decision)</td>
<td>0.7375</td>
<td>0.0432</td>
</tr>
<tr>
<td>$\delta_i$ (Carryover Rate of Information in Statin Choice)</td>
<td>0.7028</td>
<td>0.2102</td>
</tr>
<tr>
<td>$\delta_p$ (Carryover Rate of Persuasive Detailing in Statin Choice)</td>
<td>0.8878</td>
<td>0.0466</td>
</tr>
<tr>
<td>Standard Deviation of $e_{jt}$ (in Hundred Thousand)</td>
<td>0.3213</td>
<td>0.0207</td>
</tr>
</tbody>
</table>

### Log Likelihood

| Log Likelihood                                                                       | -2064.56  |

Estimates shown in bold are significant at 5% level.
The estimate of the correlated learning parameter ($\rho_0$) is 0.658, which suggests a partial information spill-over.

The estimates of both persuasive ($\kappa_d$) and informative ($\alpha_d$) detailing parameters are positive and significant.

The information carryover rate of physicians ($\delta_p$) is 0.89 per quarter.

Publicity in reducing heart disease risks ($\alpha_{rh}$) has a significant impact on updating physicians about clinical trial information.

Only aggregate detailing stock ($\alpha_{d}^s$) matters in adoption stage.
Expt 2: No Correlated Learning

Introduction Data Model Results Conclusion

Number of Prescriptions (Millions)

- Mevacor
- Pravachol
- Zocor
- Lipitor
- Crestor

(Benchmark)
Expt 3: No Switching Cost

Introduction

Data

Model

Results

Conclusion

<table>
<thead>
<tr>
<th>Year</th>
<th>Mevacor</th>
<th>Pravachol</th>
<th>Zocor</th>
<th>Lipitor</th>
<th>Crestor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1/1993</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Q1/1994</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Q1/1995</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Q1/1996</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Q1/1997</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Q1/1998</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Q1/1999</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Q1/2000</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Q1/2001</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Q1/2002</td>
<td>4.5</td>
<td>4.5</td>
<td>4.5</td>
<td>4.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Q1/2003</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Q1/2004</td>
<td>5.5</td>
<td>5.5</td>
<td>5.5</td>
<td>5.5</td>
<td>5.5</td>
</tr>
</tbody>
</table>

(Benchmark)
Our results suggest that late mover advantages can be generated by correlated learning.

Although Lipitor can free-ride on incumbents’ clinical trials, its own clinical trial is still significant for demand.

This model can be extend to other market where products qualities are uncertain, e.g., Ipad vs Android tablet.