The Impact of Innovation on Product Usage: A Dynamic Model with Progression in Content Consumption

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Studying Product Usage

- Explain product usage with:
  - innovation through product updates or launch of content
  - progression in content consumption

TV Series “24” - 8 Seasons

Angry Birds – Multiple Levels/Updates

Harry Potter – 7 Books
Product Usage

- time consuming activity
  - e.g., online games: the average number of hours per week has gone up from 7.3 hours in 2009 to 8 hours in 2010
  - e.g. soap operas: “the average Briton spends almost a year of their life watching soap operas”
- essential to explain loyalty and repeat-purchase
- determinant for the introduction of new content or product updates
Motivation and Contribution

Studying Product Usage

- However, it has not been frequently studied, mostly due to lack of data (mostly surveys, experiments)
- Emergence of new data sets that track product usage, especially in online environments
  - e.g., dataset on cell-phone usage; location tracking within stores; behavior of software users in cloud services
  - e.g., Wall Street Journal, June 29, “Your E-Book Is Reading You”, market segmentation and targeting:
    - according to data collected by digital publisher Coliloquy from romance-novel readers: “The perfect man, has a European accent and is in his 30s with black hair and green eyes.”
Contribution

- Propose a demand model that explains product usage patterns: what content do individuals consume?
- Provide insights for managerial decisions regarding innovation and product updates:
  - segmentation: how do different consumer segments change usage patterns as a response to product updates?
  - innovation rate: what is the value for the firm of a product update measured through participation rates?
  - scheduling of product updates: can the schedule of innovation be used to manage overall consumer participation?
Data - *World of Warcraft*

- Online computer game *World of Warcraft*, with 11 million players worldwide in 2010
- Users assume a character that explores an online environment

**Product Updates and Progression**

- Content is introduced over time (choice set) and follows a sequence in the storyline (20 levels)
- Players can choose to progress in the storyline by consuming the latest content

- Revenues directly related to usage through subscription and time-based pricing
Consumer Decisions

- Daily level decisions of a sample of 350 experienced players
- Decision: which content to consume or which task to perform in the game
Model

- Consumer $i$ is deciding to do action $j$, at time $t$, or an outside option.
- Action $j_p$ of product update $p$ is ranked with a level of progression $l_j$.
- Innovation/Product updates ($p = 1, ..., P$):
  - expand the choice set of content available
  - introduce content of higher progression levels
- Progression in content consumption:
  - at time $t$, consumers are in state $l_{it}$, defined by the highest-level task performed to date $t$. 
Per-period Utility

- Per-period utility of enjoying content or doing action \( j \) (of patch \( p \)) at time \( t \) for individual \( i \) (of level \( l \))

\[
u_{ijpt} = \alpha_0i + \alpha_1j + \alpha_2X_t + \beta_1ip\tau_{ipt} + \beta_2ip\tau_{ipt}^2 + \]

Intrinsic Preferences \hspace{1cm} Novelty

\[
\gamma_i \cdot |l_{it} - l_j| + \delta_1i \cdot |l_{it} - \bar{l}_t| + \delta_2iG_{it} + \epsilon_{ijt}
\]

Content Match \hspace{1cm} Community Effect

- Components from literature on product usage (e.g., Holbrook and Hirschman, 1982)

- The determinist utility of the outside good is set to zero
**Model Dynamics**

- **States:** \( S_{it} = \{l_{it}, \tau_{ipt}, X_t, p_t\} \)

- **State transitions, denoted by** \( \pi(S_{it+1} \mid S_{it}) \):
  - individuals progress if they perform an action of higher level
  - novelty/satiation changes as \( \tau \) advances by one period
  - more available choices when a product update is introduced

- **Consumer expectations and knowledge:**
  - launch date and number of updates: based on historic launch schedule and number
  - future \( \alpha_j \) and community level \( \bar{l}_t \): based on past observed values, characteristics of content and evolution
Choice Probabilities and Likelihood

- Complete utility of action $a_{it}$ and choice probabilities, with parameter vector $\Theta_i$:

$$v(a_{it}, S_{it}; \Theta_i) = u(a_{it}, S_{it}; \Theta_i) + \delta \int_S V_{t+1}(S_{it+1}; \Theta_i) \pi(S_{it+1}|S_{it}, a_{it}) dS_{it+1},$$

$$Pr(a_{it}, S_{it}; \Theta_i) = \frac{\exp(v(a_{it}, S_{it}; \Theta_i))}{\sum_{a'\in A_t} \exp(v(a'_{it}, S_{it}; \Theta_i))}.$$

- Likelihood over individuals $i$ and over time $t$

$$Log \ Likelihood = \sum_{i=1}^{N} \sum_{t=1}^{T} (a_{it} \log(Pr(a_{it}, S_{it}, \Theta)))$$

where $a_{it}$ is the realized action of individual $i$ at time $t$
Estimation

- Constraint optimization (Su and Judd, 2011), which replaces backwards induction
  - maximize data likelihood subject to a consumer value function
- Expectation-Maximization (EM) algorithm (Arcidiacono and Jones, 2007),
  - unobserved heterogeneity with discrete segments in a forward-looking setting
Parameter Estimates

- Three distinct segments: hard-core players (seg. 2); laggards (seg. 1); average player (seg. 3)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Segment 1</th>
<th>Segment 2</th>
<th>Segment 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Intercepts ($\alpha$)</td>
<td>-13.297 (0.375)</td>
<td>-6.835 (0.081)</td>
<td>-8.111 (0.118)</td>
</tr>
<tr>
<td>Match with Task ($\gamma$)</td>
<td>-0.674 (0.013)</td>
<td>-1.131 (0.035)</td>
<td>-0.645 (0.020)</td>
</tr>
<tr>
<td>Community Effect ($\delta$)</td>
<td>-0.118 (0.241)</td>
<td>0.580 (0.023)</td>
<td>0.235 (0.058)</td>
</tr>
<tr>
<td>Segment size</td>
<td>0.258 (0.010)</td>
<td>0.338 (0.010)</td>
<td>0.404 (0.010)</td>
</tr>
</tbody>
</table>
Progression by Segment

- Segment 1
- Segment 2
- Segment 3

Legend:
- mean level of a segment
- mean level of tasks completed by gamers in a segment
- mean level of overall gamers population
Three waves of distinct consumers
Counterfactual I: Evaluating a Product Update

- Removed product update 3 from the market
- Tasks: 16,001 vs. 13,966 (-12.7%) = $8.5 million in revenues
Counterfactual II: Postponing one Product Update

- Analyzing the decision to postpone the last product update by 2 months (from time period 421 to 477)
- Product updates can be used to manage usage and peak usage of innovators only
Conclusions

- Model to explain product usage: which content to consume?
  - analyze demand patterns: what motivates usage over time for different segments?
  - how many product updates to launch?
  - when to launch those product updates?

- Substantive results:
  - targeting: product updates communicated at the correct time and customized to be available to the right users
  - value of innovation is largely driven by users that have explored all aspects of the product, who motivate others
  - scheduling is important to manage usage load, but mostly of innovators