Designing Price Contracts for Boundedly Rational Customers: Does the Number of Block Matter?

Teck H. Ho
University of California, Berkeley

Forthcoming, *Marketing Science*

Coauthor:
Noah Lim, University of Houston

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Outline

- Motivation
- Does the Number of Block Matter?
- Economic Hypotheses
- A Behavioral (and General) Approach
Motivation

- B2C \(\Rightarrow\) B2B

- Integration of economics and psychology
  \(\Rightarrow\) Combine the strengths of economics and psychology

- Lack of behavioral data in real B2B settings
  \(\Rightarrow\) Study laboratory B2B settings
Integration of Economics and Psychology (Johnson 2006)

Figure 2: Cross Citation of Three Major Marketing Journals and Groups of Related Journals

KEY
> 21%
17-21%
13-17%
9-13%
5-9%
## Behavioral Economics Models

(Ho et al. 2006)

<table>
<thead>
<tr>
<th>Behavioral Regularities</th>
<th>Standard Assumptions</th>
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<th>New Parameters (Behavioral Interpretation)</th>
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<td>(\omega) (weight on transaction utility)</td>
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<td></td>
</tr>
<tr>
<td>Fairness and social preferences</td>
<td>Pure self-interest</td>
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</tr>
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<td></td>
<td></td>
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<td></td>
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<td>Impatience and taste for instant gratification</td>
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<td>(\beta) (preference for immediacy, “present bias”)</td>
<td>Price plans for gym memberships</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>New Methods of Game-Theoretic Analysis</th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Noisy best-response</td>
<td>Best-response property</td>
<td>Quantal response equilibrium (McKelvey and Palfrey 1995)</td>
<td>(\lambda) (better-response sensitivity)</td>
<td>Price competition with differentiated products</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Thinking steps</td>
<td>Rational expectations hypothesis</td>
<td>Cognitive hierarchy (Camerer, Ho, and Chong 2004)</td>
<td>(\tau) (average number of thinking steps)</td>
<td>Market entry</td>
</tr>
<tr>
<td>Adaptation and learning</td>
<td>Instant equilibration</td>
<td>Self-tuning EWA (Ho, Camerer, and Chong, in press)</td>
<td>(\lambda) (better-response sensitivity)</td>
<td>Lowest-price guarantees</td>
</tr>
</tbody>
</table>

\(^*\)There are two additional behavioral parameters \(\phi\) (change detection, history decay) and \(\zeta\) (attention to forgone payoffs, regret) in the self-tuning EWA model. These parameters do not need to be estimated; they are calculated on the basis of feedback.

Notes: EWA = experience-weighted attraction.
Examples of Pricing Contracts

- Linear
- Two-part Tariff
- Three-part Tariff
- Multi-Block Tariff
A Simple Framework

Number of Block

<table>
<thead>
<tr>
<th>Fixed Fee</th>
<th>Single</th>
<th>Multiple</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>Linear</td>
<td>Block-tariff (2B vs. 3B)</td>
</tr>
<tr>
<td>Yes</td>
<td>Two-part Tariff</td>
<td>Three-part Tariff</td>
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</tbody>
</table>
Does Number of Block Matter?

Number of Block

<table>
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<td>Three-part Tariff</td>
</tr>
</tbody>
</table>

Fixed Fee

- No
- Yes
Research Question

Does the Number of Block Matter Empirically?

- Total surplus generated from trading
- Division of surplus (e.g., which format favors the seller)
A B2B Market: The Mapping between Real and Laboratory Settings

Independent

Manufacturer (seller) C = 20

Retailer (Buyer)

Demand = 100 - price

Example

Which Type of Pricing Contract to Use?

Price Contract

Office Depot USA

Price

Which Type of Pricing Contract to Use?

Price Contract

Office Depot USA

Price

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Integrated Manufacturer and Retailer

Demand = 100 - price

Manufacturer

Retailer

C = 20

Price* = 60

Manufacturer Profits

Retailer Profits

* Assume equal division

0 800 1600 Retailer Profits

0 800 1600 Manufacturer Profits

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Linear Price

**Independent**

Demand = 100 - price

\[ W^* = 60 \]

\[ \text{Price}^* = 80 \]

\[ C = 20 \]

**Total Surplus (Integrated) > Total Surplus (Independent)**
Two-Block Tariff

Manufacturer

Retailer

C = 20

W1, X1, W2 = 20

Price* = 60

Demand = 100 - Price

Total Cost to Retailer

2-Block Tariff

Manufacturer Profits

Retailer Profits

M = (W1 - W2)X1

1600-M

1600

1600

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Number of Block: 2B vs. 3B

\[
\begin{align*}
W2 &= 20 \quad \text{(2B & 3B)} \\
M &= (W1-W2)X1 \quad \text{(2B)} \\
&= (W0-W2)X0 + (W1-W2)(X1-X0) \quad \text{(3B)}
\end{align*}
\]
1. Revenue Equivalence (Strong)

Manufacturer Profits ($\pi_M$)

Retailer Profits ($\pi_R$)

\[
\pi_M(X) = \delta(X) + \kappa(X)\pi_R(X)
\]
\[
\pi_M(Y) = \delta(Y) + \kappa(Y)\pi_R(Y)
\]

Constraints:
\[
\kappa(X) = \kappa(Y) = -1
\]
\[
\delta(X) = \delta(Y) = 1600
\]

\[X = 2B\quad ; \quad Y = 3B\]
2. Revenue Equivalence (Weak)

\[ \pi_M(X) = \delta(X) + \kappa(X) \pi_R(X) \]
\[ \pi_M(Y) = \delta(Y) + \kappa(Y) \pi_R(Y) \]

Constraints:
\[ \delta(X) = \delta(Y) \]
\[ \kappa(X) = \kappa(Y) = -1 \]

\[ X = 2B \quad ; \quad Y = 3B \]
3. Division Equivalence

Manufacturer Profits ($\pi_M$)

Retailer Profits ($\pi_R$)

Constraints: $\delta_{(X)} = \delta_{(Y)} = 0$

$\delta_{(X)} = \delta_{(Y)} = 0$

$\kappa_{(X)} = \kappa_{(Y)}$

$\pi_M(X) = \delta_{(X)} + \kappa_{(X)}\pi_R(X)$

$\pi_M(Y) = \delta_{(Y)} + \kappa_{(Y)}\pi_R(Y)$

$X = 2B$ ; $Y = 3B$
Empirical Equivalence

Manufacturer Profits ($\pi_M$)

Retailer Profits ($\pi_R$)

$X = Y$

$X = 2B$ ; $Y = 3B$
Testable Hypotheses

Number of Block

Total Pie

1600
1200

M’s Share of Pie

100%
67%

Number of Block

H1
H2
H3
H4
Economic Experiments

• Vary Number of Blocks: 1-Block (Linear Price), 2-Block tariff, and 3-Block tariff Price contracts.

• Subjects are business students and working managers.

• Subjects were told the following:
  • Decision-making experiment and they will earn cash according to the decision points they obtain.
  • 11 subjects per session with 11 rounds. 2 sessions per contract.
  • Each subject is randomly matched with another subject only once.
  • They will either be a RED player (Manufacturer) or BLUE player (Retailer) in each round.
  • RED sells a product to BLUE, who in turn sells it to a group of customers.
  • RED’s unit cost is 20. Customers’ Demand is Quantity =100-Price.
Subjects’ Decisions

- 2-Block and 3-Block tariffs (between-subjects): RED offers BLUE a quantity discount contract.
- RED chooses X, Y and Break (w1, w2 and x1 respectively). In 3-Block contract, we fixed w0 and x0 to control for decision complexity.
Subjects’ Payoffs

- **BLUE** observes **RED**’s contract offer of $w_1$, $w_2$ and $x_1$.
- **BLUE** chooses Price, which determines Quantity sold according to $\text{Quantity} = 100 - \text{Price}$.

- E.g., For 2-Block tariff:

  If $\text{Quantity} \leq \text{Break}$,
  \[
  \text{RED profits} = [X - 20] \times \text{Quantity} \\
  \text{BLUE profits} = [\text{PRICE} - X] \times \text{Quantity}
  \]

  If $\text{Quantity} > \text{Break}$,
  \[
  \text{RED profits} = [X \times \text{Break}] + [Y \times (\text{Quantity} - \text{Break})] - [20 \times \text{Quantity}] \\
  \text{BLUE profits} = [\text{Price} \times \text{Quantity}] - [X \times \text{Break}] - [Y \times (\text{Quantity} - \text{Break})]
  \]

- **BLUE** can also Reject the contract and both players earn zero points.
Students versus Managers

Managers (Full-time and Part-time MBA students), Stake Size Doubled, Groups of 4, Instructions given out 7 days in advance.

<table>
<thead>
<tr>
<th>2-Block Tariff</th>
<th>Undergrad (1)</th>
<th>MBA (2)</th>
<th>t-stat (1 v 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td>80%</td>
<td>83%</td>
<td>-0.95</td>
</tr>
<tr>
<td>M’s share of total profits</td>
<td>65%</td>
<td>68%</td>
<td>-1.27</td>
</tr>
</tbody>
</table>

Conditional on retailer accepting contract.
Scatter-Plots: 2- versus 3-Block Tariff

2-Block Tariff

3-Block Tariff

$\pi_M$ $\pi_R$

$\pi_M$ $\pi_R$
# H1 and H3: 1- versus 2-Block

<table>
<thead>
<tr>
<th></th>
<th>Theory Prediction (1-Block)</th>
<th>Actual 1-Block</th>
<th>Theory Prediction (2-Block)</th>
<th>Actual 2-Block</th>
<th>t-stat (2 v 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Efficiency</strong></td>
<td>75%</td>
<td>67%</td>
<td>100%</td>
<td>81%</td>
<td>H1: 5.24*</td>
</tr>
<tr>
<td><strong>Manufacturer’s Share of Profits</strong></td>
<td>67%</td>
<td>64%</td>
<td>100%</td>
<td>65%</td>
<td>H3: 0.80</td>
</tr>
</tbody>
</table>

*significant at the 5% level. Conditional on Retailer accepting contract.
### H2 and H4: 2- versus 3-Block

<table>
<thead>
<tr>
<th></th>
<th>Theory Prediction</th>
<th>2-Block</th>
<th>3-Block</th>
<th>t-stat (2 v 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( w_2 )</td>
<td>20</td>
<td>34</td>
<td>30</td>
<td>2.81*</td>
</tr>
<tr>
<td>Price</td>
<td>60</td>
<td>74</td>
<td>66</td>
<td>6.85*</td>
</tr>
<tr>
<td>Efficiency</td>
<td>( H_2: 2B=3B )</td>
<td>81%</td>
<td>95%</td>
<td>-6.55*</td>
</tr>
<tr>
<td></td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M’s Share of Total Profits</td>
<td>( H_4: 2B=3B )</td>
<td>65%</td>
<td>73%</td>
<td>-4.03*</td>
</tr>
<tr>
<td></td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*significant at the 5% level

Conditional on Retailer accepting contract
Empirical Regularities

Number of Block

Total Pie

H1

H2

1

2

3

1200

1600

M’s Share of Pie

100%

67%

Number of Block

H3

H4

1

2

3

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Quantal Response Equilibrium (QRE)

- **Empirical Puzzle 1**: Retailer choose to buy in the “last block” less often in 2-Block vs. 3-block (only 60% compared to 83% for accepted contracts), whereas theory predicts retailer doing so all the time.

- **QRE Model**: Allow Retailer to be less than perfectly sensitive to payoffs across blocks (i.e., noisily best respond)

```
0

U_R^l (q \leq x_1)  U_R^r (q > x_1)
```

"Reject"  "Left"  "Right" (Last Block)
Assume that the retailer follows a multinomial logit choice rule so that the probability of the retailer choosing ‘Right’ is

\[
\frac{e^{\gamma U^r_R}}{1 + e^{\gamma U^l_R} + e^{\gamma U^r_R}}
\]

- Parameter \( \gamma \) captures the sensitivity to differences in monetary payoffs.
- Manufacturer takes retailer’s decision rule into account. Sets the contract by maximizing the following expected profit function:

\[
E(\pi_M) = \frac{e^{\gamma U^l_R}}{1 + e^{\gamma U^l_R} + e^{\gamma U^r_R}} \cdot \pi^l_M + \frac{e^{\gamma U^r_R}}{1 + e^{\gamma U^l_R} + e^{\gamma U^r_R}} \cdot \pi^r_M + \frac{1}{1 + e^{\gamma U^l_R} + e^{\gamma U^r_R}} \cdot 0
\]
Reference-Dependent Payoffs

• **Empirical Puzzle 2**: \( w_2 \) and Price are higher in 2-block (vs. 3-Block)

• Retailer’s wants lower adjacent marginal price it pays to apply to the previous block.

• Let \( \beta \) be the value of every counterfactual dollar.

• Example: For 2-Block tariff, Retailer’s Utility is:

\[
U^R = \begin{cases} 
  U^l_R = \pi^l_R & \text{if } 0 < q \leq x_1 \\
  U^r_R = \pi^r_R - \beta(w_1 - w_2)x_1 & \text{if } q > x_1
\end{cases}
\]
Model Estimation

- Manufacturer’s decisions are iid with a bivariate normal density:

\[
\begin{pmatrix}
    w_{1it} \\
    w_{2it}
\end{pmatrix} \sim \mathcal{N}\left(\begin{pmatrix}
    w_1^* \\
    w_2^*
\end{pmatrix}, \begin{pmatrix}
    \sigma_{w_i}^2 & \rho_{12}\sigma_{w_i}\sigma_{w_2} \\
    \rho_{12}\sigma_{w_2}\sigma_{w_i} & \sigma_{w_2}^2
\end{pmatrix}\right)
\]

- \(w_1^*\) and \(w_2^*\) are the equilibrium predictions (solved numerically) of the QRE model with counterfactual profits.

- Estimate common \(\beta\) and contract-specific \(\gamma\).
Likelihood Function

- Log-Likelihood function for each contract is:

\[
LL (\beta, \gamma, \sigma_{w_1}, \sigma_{w_2}, \rho_{12}) =
\]

\[
\sum_{i=1}^{N} \sum_{t=1}^{T} \left\{ -\ln(2\pi) - \frac{1}{2} \ln |\Sigma| - \frac{1}{2} (\Omega' \Sigma^{-1} \Omega) + \text{Reject}_{it} \cdot \ln \left( \frac{1}{1 + e^{U_{R}^l} + e^{U_{R}^r}} \right) \right\}
\]

\[
+ \text{Left}_{it} \cdot \ln \left( \frac{e^{U_{R}^l}}{1 + e^{U_{R}^l} + e^{U_{R}^r}} \right) + \text{Right}_{it} \cdot \ln \left( \frac{e^{U_{R}^r}}{1 + e^{U_{R}^l} + e^{U_{R}^r}} \right)
\]

where \( \Sigma = \begin{pmatrix} \sigma_{w_1}^2 & \rho_{12} \sigma_{w_1} \sigma_{w_2} \\ \rho_{12} \sigma_{w_2} \sigma_{w_1} & \sigma_{w_2}^2 \end{pmatrix} \) and \( \Omega = \begin{pmatrix} w_{1it} - w_1^* \\ w_{2it} - w_2^* \end{pmatrix} \)
## Estimation Results

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Full Model</th>
<th>Nested Model $\gamma_{2B} = \gamma_{3B} = 0.2^*$</th>
<th>Nested Model $\beta = 0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>0.196</td>
<td>0.126</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(8.10)</td>
<td>(35.00)</td>
<td></td>
</tr>
<tr>
<td>$\gamma_{2B}$</td>
<td>0.0036</td>
<td></td>
<td>0.0016</td>
</tr>
<tr>
<td></td>
<td>(7.08)</td>
<td></td>
<td>(9.30)</td>
</tr>
<tr>
<td>$\gamma_{3B}$</td>
<td>0.0107</td>
<td></td>
<td>0.0048</td>
</tr>
<tr>
<td></td>
<td>(7.12)</td>
<td></td>
<td>(26.06)</td>
</tr>
<tr>
<td>-LL</td>
<td>2186.7</td>
<td>4431.2</td>
<td>2225.8</td>
</tr>
</tbody>
</table>

*To approximate large value of $\gamma$. Figures in parentheses are the t-statistics.*
## Model Predictions: 2 Block

<table>
<thead>
<tr>
<th>Variable</th>
<th>Actual Data</th>
<th>Predictions</th>
</tr>
</thead>
<tbody>
<tr>
<td>w1</td>
<td>63.7</td>
<td>63.51</td>
</tr>
<tr>
<td>w2</td>
<td>34.0</td>
<td>32.20</td>
</tr>
<tr>
<td>Left</td>
<td>0.36</td>
<td>0.39</td>
</tr>
<tr>
<td>Right</td>
<td>0.53</td>
<td>0.50</td>
</tr>
<tr>
<td>Reject</td>
<td>0.11</td>
<td>0.12</td>
</tr>
<tr>
<td>Conditional Efficiency</td>
<td>80.8%</td>
<td>85.7%</td>
</tr>
<tr>
<td>m</td>
<td>65.3%</td>
<td>67.9%</td>
</tr>
</tbody>
</table>
# Model Predictions: 3 Block

<table>
<thead>
<tr>
<th>Variable</th>
<th>Actual Data</th>
<th>Predictions</th>
</tr>
</thead>
<tbody>
<tr>
<td>W1</td>
<td>57.3</td>
<td>56.1</td>
</tr>
<tr>
<td>w2</td>
<td>29.9</td>
<td>28.4</td>
</tr>
<tr>
<td>Left</td>
<td>0.11</td>
<td>0.11</td>
</tr>
<tr>
<td>Right</td>
<td>0.74</td>
<td>0.82</td>
</tr>
<tr>
<td>Reject</td>
<td>0.15</td>
<td>0.06</td>
</tr>
<tr>
<td>Conditional Efficiency</td>
<td>95.1%</td>
<td>96.0%</td>
</tr>
<tr>
<td>$m$</td>
<td>72.7%</td>
<td>77.4%</td>
</tr>
</tbody>
</table>
Future Research

- A mini field application project at HP
- Field data (B2B pricing contract data from HP)
- Other pricing contracts (Two-part tariff vs. quantity discount contract)
- B2C settings (mobile phone plans, 3-block tariffs)
## HP Printing Division Go-to-Market Strategy

**Design and Analysis**

### Business Objective
- Optimize incentives for IPG new product business

### Policy Issues
- Fixed vs % target before discount kicks in
- 2-block versus 3-block tariffs

### Experimental Design
- Stanford students as subjects held at HP Labs
- One new and one old product in IPG Commercial Value-added Reseller Program
- Demand model calibrated with business inputs
  - Reseller competence / sales activity modeling
  - Demand drivers

### Research Results
- Fixed threshold better quantity discount policy
- 3-block is better for several retailers

### Business Results
- HP adopted all recommendations
Does Contract Framing Matter?

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<tr>
<td>Yes</td>
<td>Two-part Tariff (Salient vs. Opaque)</td>
<td>Three-part Tariff</td>
</tr>
</tbody>
</table>
Thank You
A “Tighter” Test of H2

- Define $Z = 1600$-Total Profits.
- Let $Z$ be distributed with density $f(Z)$ for $Z > 0$, where $f(Z)$ is exponential with parameter $\lambda$.
- $f(0) = 0$.
- Let $y$ be the probability that $Z = 0$.
- Likelihood function of $Z$ with $n$ observations:

$$L(y, \lambda) = \prod_{i=1}^{n} \left\{ y \cdot I(Z) + (1 - y) \cdot f(Z) \right\}$$

where $I(Z) = \begin{cases} 1 & \text{if } Z = 0, \\ 0 & \text{otherwise} \end{cases}$

- Key is to test whether model where values of $y$ and $\lambda$ are equal across the 2 and 3 Block contracts can be accepted.
Parameter Estimates and L-R Tests

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Exponential</th>
</tr>
</thead>
<tbody>
<tr>
<td>$y_{2B}$</td>
<td>0.077</td>
</tr>
<tr>
<td>$y_{3B}$</td>
<td>0.172</td>
</tr>
<tr>
<td>$\lambda_{2B}$</td>
<td>0.0030</td>
</tr>
<tr>
<td>$\lambda_{3B}$</td>
<td>0.0105</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Constraints</th>
<th>Exponential (-LL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unconstrained Model</td>
<td>1322.60</td>
</tr>
<tr>
<td>$y_{2B} = y_{3B}$</td>
<td>1324.95 (4.70)*</td>
</tr>
<tr>
<td>$\lambda_{2B} = \lambda_{3B}$</td>
<td>1354.70 (64.20)*</td>
</tr>
<tr>
<td>$y_{2B} = y_{3B}$, $\lambda_{2B} = \lambda_{3B}$</td>
<td>1357.04 (68.88)*</td>
</tr>
</tbody>
</table>

All estimated parameters are significant.
Testable Hypotheses

- H1: Total channel profits increase as the number of blocks in a price contract changes from 1 to 2.

- H2: Total channel profits remain unchanged as the number of blocks changes from 2 to 3.

- H3: Manufacturer’s share of total profits increases from 66.7% in the 1-Block contract to 100% in the 2-Block contract.

- H4: Manufacturer’s share of total profits remain unchanged at 100% as the number of blocks increases from 2 to 3.
Empirical Regularities

1. Total profits increases as number of blocks increases from 1 to 2. (H1 supported)

2. Total profits increases even as number of blocks increases from 2 to 3 (H3 not supported)

3. Manufacturer’s share of profits does not increase as number of blocks changes from 1 to 2 (H2 not supported).

4. Manufacturer’s share of profits increases as number of blocks changes from 2 to 3, but still far below the 100% predicted (H4 not supported).