Competition-Based Dynamic Pricing In Online Retailing

Research Collaboration with Yihaodian

Marshall Fisher ◦ The Wharton School
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Gang Yu ◦ Yihaodian, Co-Founder and Chairman

List Price: $199.95

amazon.com

PRICE MATCH GUARANTEE

Add to Cart

$199.99

FREE SHIPPING

on orders $35 and up

$175.99

Eligible for Shop Your Way Points

For 48109 change location

Eligible for Free Shipping From FactoryOutletStore.com

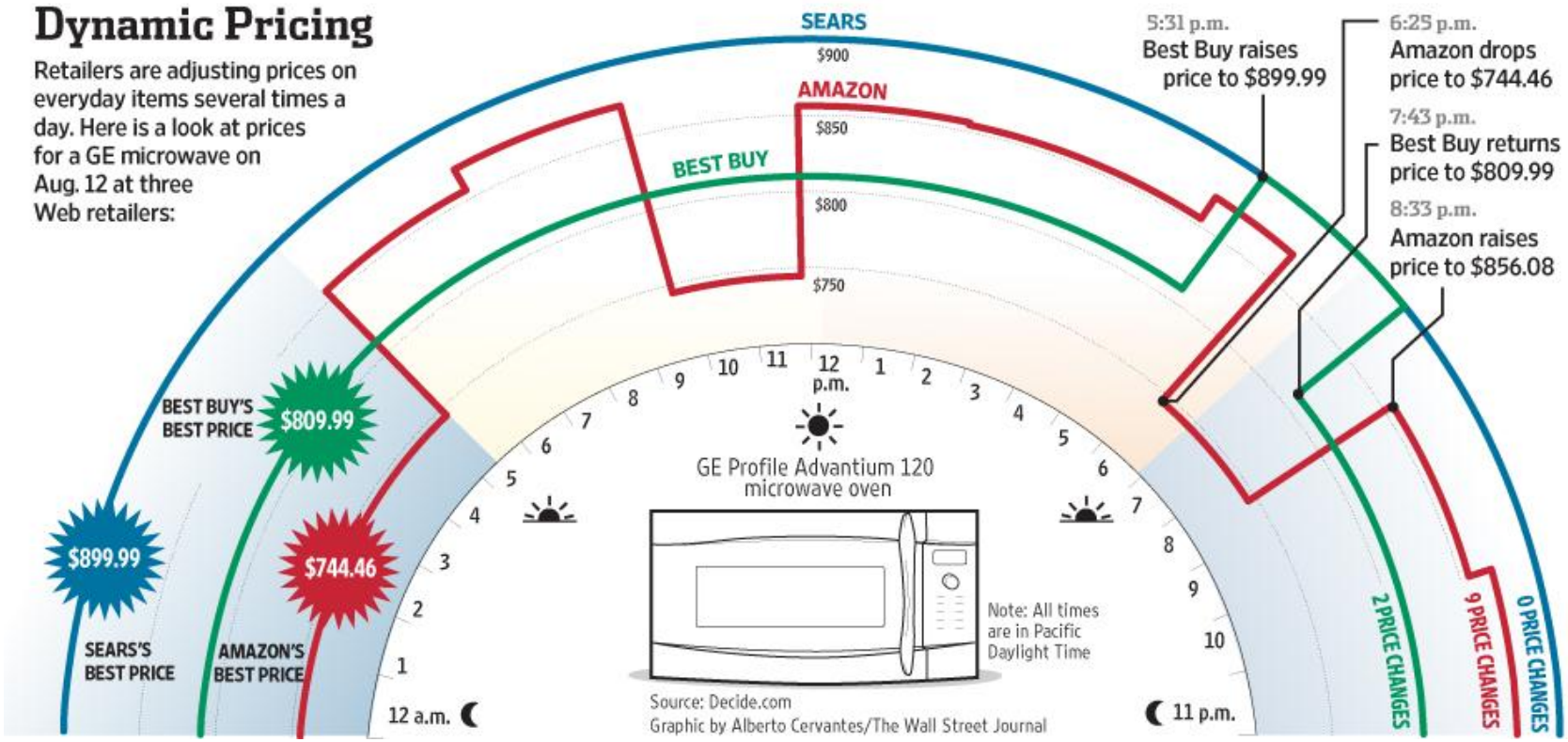
sears

Reduced Price

$143.00

Was: $210.41 (You save $67.41)

FREE shipping


Dynamic Pricing
Retailers are adjusting prices on everyday items several times a day. Here is a look at prices for a GE microwave on Aug. 12 at three Web retailers:
SEARS
AMAZON
BEST BUY
$900
$850
$800
$750
5:31 p.m.
Best Buy raises price to $899.99
6:25 p.m.
Amazon drops price to $744.46
7:43 p.m.
Best Buy returns price to $809.99
8:33 p.m.
Amazon raises price to $856.08
BEST BUY'S BEST PRICE
$809.99
$899.99
SEARS'S BEST PRICE
$744.46
AMAZON'S BEST PRICE
12 a.m.
12 p.m.
11 p.m.
GE Profile Advantium 120 microwave oven
Note: All times are in Pacific Daylight Time
2 PRICE CHANGES
9 PRICE CHANGES
0 PRICE CHANGES
Source: Decide.com
Graphic by Alberto Cervantes/The Wall Street Journal

Respond?

To Whom?

By How Much?

Sunbeam SGS90701B-B 0.7-Cubic Foot Microwave Oven,...

$69.00 ~~$79.99~~ Prime

#2 Best Seller

in Countertop Microwave Ovens

Panasonic NN-SN651B Genius 1.2 cuft 1200 Watt Sensor...

$125.99 ~~$149.99~~ Prime

See Color Options

Nostalgia Electrics RMO770BLK Retro Series Countertop...

$59.00 ~~$99.99~~ Prime

See Color Options

Panasonic NN-SD681S Genius "Prestige" 1.2 cuft 1200 Watt...

$178.49 ~~$199.99~~ Prime

Danby 0.7 cu.ft. Countertop Microwave, White

$59.99 ~~$79.99~~ Prime

#3 Best Seller

in Countertop Microwave Ovens

Oster OGZB1101-B 1.1 Cubic Foot Digital Microwave Oven,...

$79.99 Prime

Oster OGB5902 0.9-Cubic Feet Microwave Oven, Black

$76.98 ~~$79.99~~ Prime

Oster OGH6901 0.9 Cubic Feet Digital Microwave Oven,...

$74.97 ~~$109.99~~ Prime

Panasonic NN-SD372S 0.8 Cubic Feet 950-Watt Inverter...

Oster OGB8902-B 0.9-Cubic Foot Microwave Oven, Black

$59.84 ~~$89.99~~ Prime

Panasonic Genius NN-SN773S 1.6 cuft 1250 Watt Microwave...

$211.25 ~~$229.99~~ Prime

See Size Options

Sunbeam SGS90701W-B 0.7-Cubic Foot Microwave Oven,...

$59.00 ~~$79.99~~ Prime

– $

– %

Competition-Based Dynamic Pricing

How elastic is demand?

Who do I really compete with?

Do customers shop prices across retailers?

Our Partner

Founded in 2008

Sales reach $3 billion in 2014

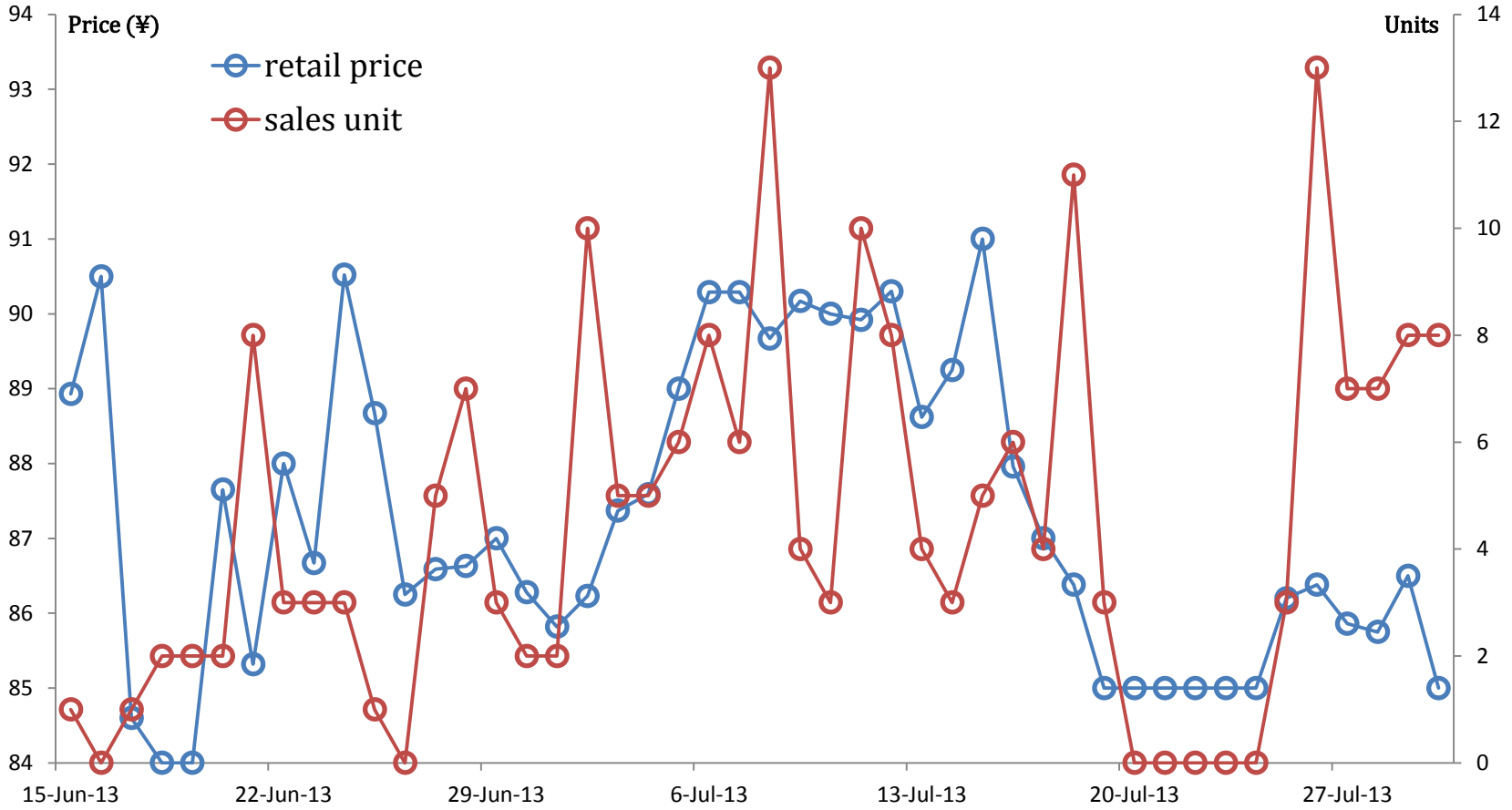
Walmart's online arm in China

Top 10 fastest growing tech company in Asia

Challenges

Endogenous Price

Challenge I – Endogenous Price

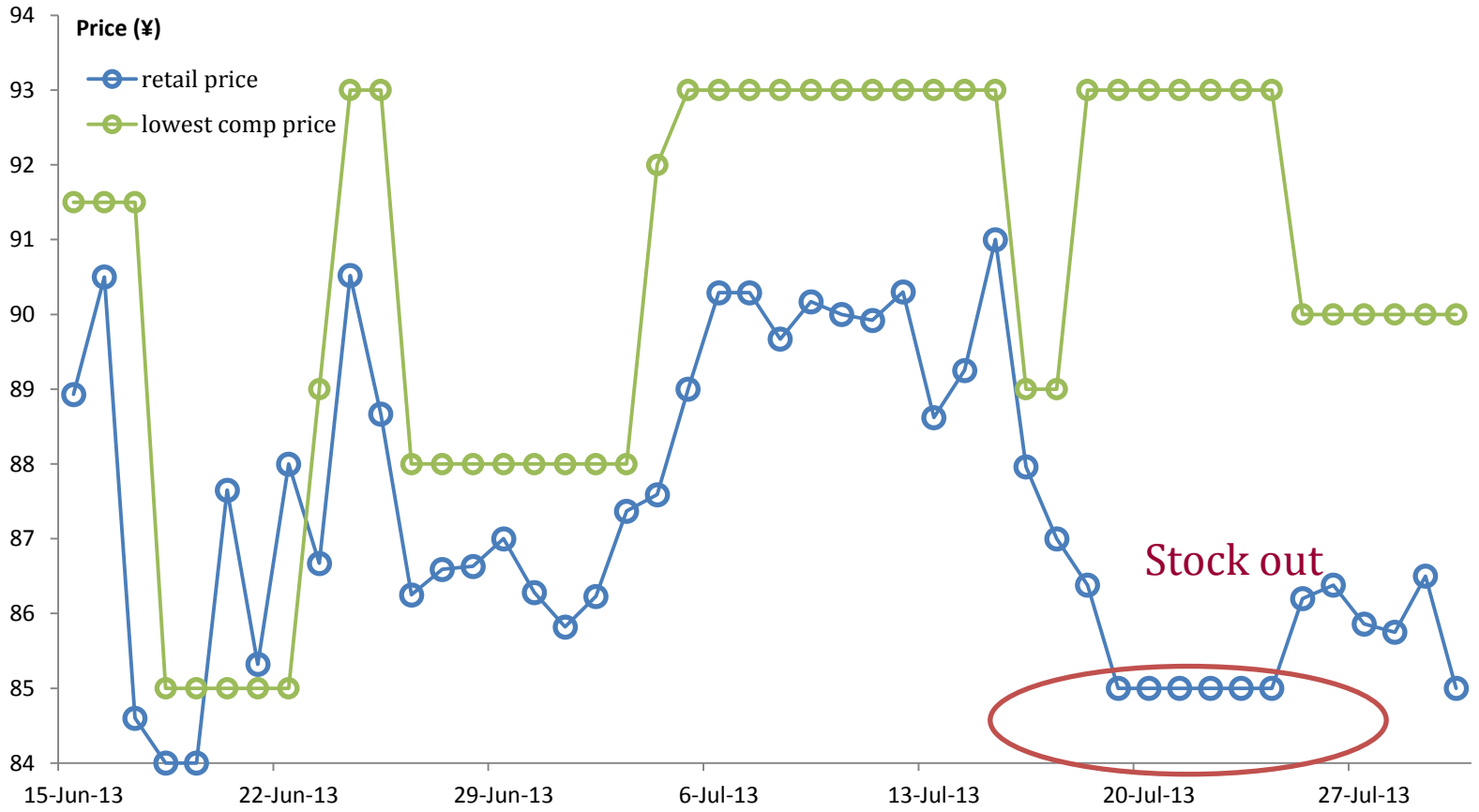


Challenges

Endogenous Price

Limited Price Variation

Challenge II: Limited Price Variation



Choice of Category

303 SKUs
Top 29 SKUs
Sales>1 per day
80.1% total revenue
Price range ¥13 ~ ¥165

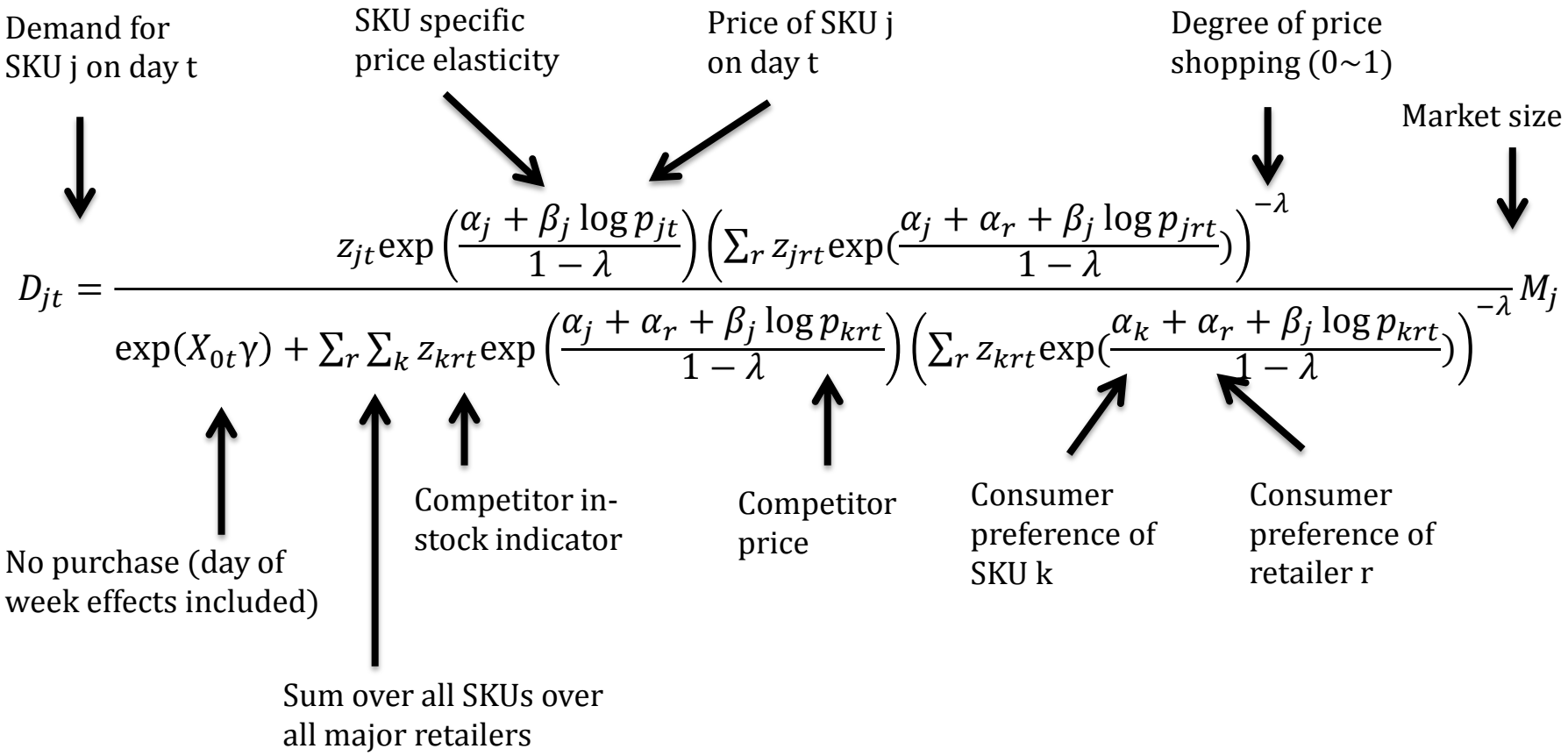
Randomized Price Experiment

PRODUCT	DAY_1	DAY_2	DAY_3	DAY_4	DAY_5	DAY_6	DAY_7	DAY_8	DAY_9	DAY_28	DAY_29	DAY_30
1	HH	HH	HH	B	B	B	L	L	L	HH	HH	HH
2	B	B	B	L	L	L	H	H	H	HH	HH	HH
3	L	L	L	H	H	H	LL	LL	LL	B	B	B
4	H	H	H	LL	LL	LL	L	L	L	L	L	L
5	LL	LL	LL	L	L	L	B	B	B	H	H	H
6	H	H	H	HH	HH	HH	L	L	L	H	H	H
7	HH	HH	HH	L	L	L	B	B	B	H	H	H
8	L	L	L	B	B	B	LL	LL	LL	HH	HH	HH
9	B	B	B	LL	LL	LL	LL	LL	LL	L	L	L
10	LL	LL	LL	LL	LL	LL	B	B	B	B	B	B
11	LL	LL	LL	B	B	B	L	L	L	LL	LL	LL
12	HH	HH	HH	LL	LL	LL	L	L	L	L	L	L
13	LL	LL	LL	L	L	L	B	B	B	HH	HH	HH
14	L	L	L	B	B	B	H	H	H	LL	LL	LL
15	B	B	B	H	H	H	LL	LL	LL	L	L	L
16	H	H	H	LL	LL	LL	HH	HH	HH	B	B	B

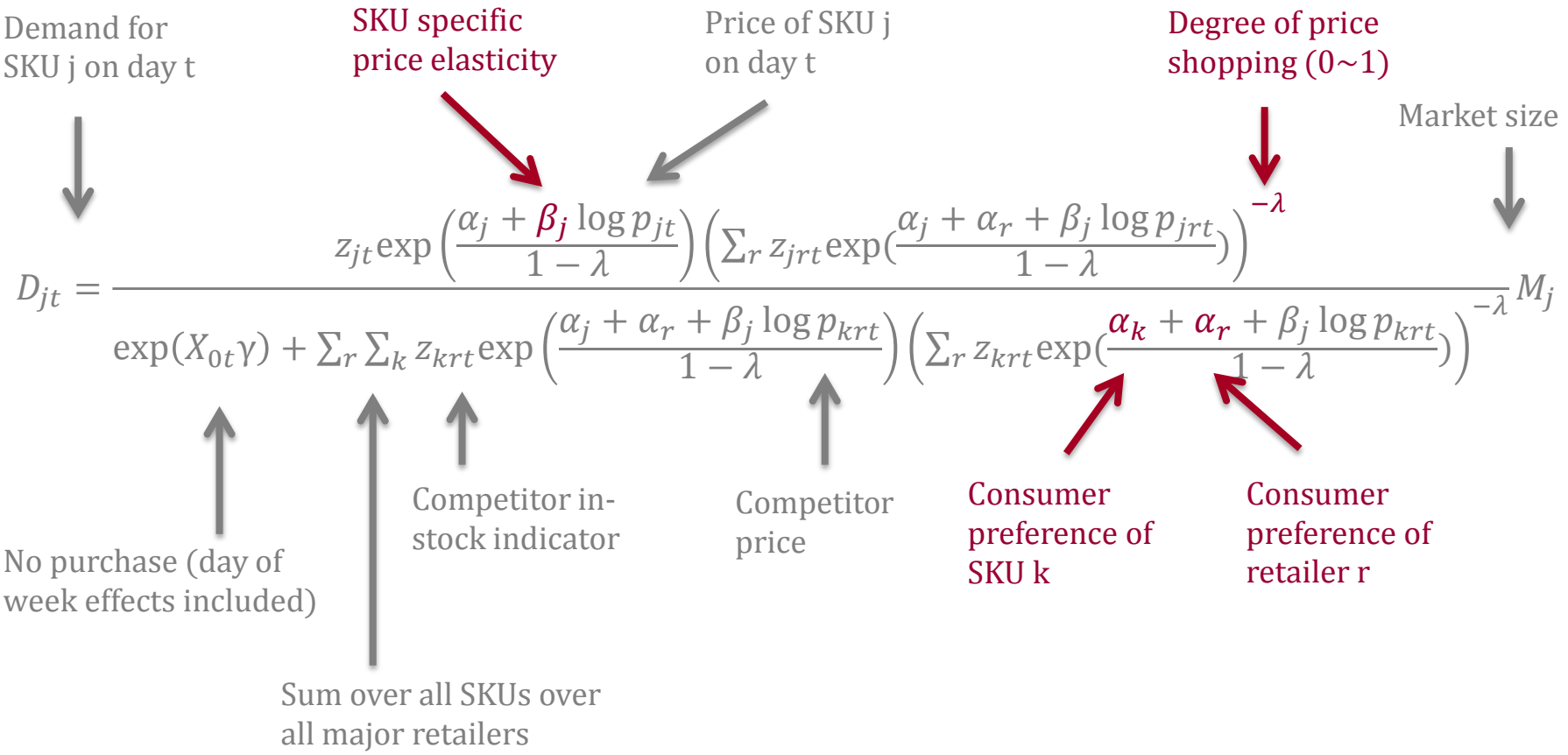
When Randomization Isn't Good Enough

Consumer Choice Set

Model


Demand for SKU j on day t
SKU specific price elasticity
Price of SKU j on day t
Degree of price shopping (0~1)
Market size
$D_{jt} = \frac{z_{jt}\exp\left(\frac{\alpha_j + \beta_j \log p_{jt}}{1-\lambda}\right)\left(\sum_r z_{jrt}\exp\left(\frac{\alpha_j + \alpha_r + \beta_j \log p_{jrt}}{1-\lambda}\right)\right)^{-\lambda}}{\exp(X_{0t}\gamma) + \sum_r \sum_k z_{krt}\exp\left(\frac{\alpha_j + \alpha_r + \beta_j \log p_{krt}}{1-\lambda}\right)\left(\sum_r z_{krt}\exp\left(\frac{\alpha_k + \alpha_r + \beta_j \log p_{krt}}{1-\lambda}\right)\right)^{-\lambda}} M_j$
No purchase (day of week effects included)
Sum over all SKUs over all major retailers
Competitor in-stock indicator
Competitor price
Consumer preference of SKU k
Consumer preference of retailer r

Model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Challenges

Endogenous Price

Limited Price Variation

Lack of Competitor Sales Data

Challenge III: Lack of Competitor Sales Data

	1号店 The Store	amazon	JD.COM 京东	当当网 dangdang.com
	Sales?	Sales?	Sales?
	Sales?	Sales?	Sales?
	Sales?	Sales?	Sales?

Stock-out as a Source of Identification

A Sketch of Identification

Suppose there are two products 1 and 2, and two retailers, Yihaodian and Competitor.

$$u_{i1Y} = \alpha_1 + \beta_1 Price_{1Y} + \varepsilon_{i1Y}$$
$$u_{i2Y} = \alpha_2 + \beta_2 Price_{2Y} + \varepsilon_{i2Y}$$
$$u_{i1C} = \alpha_1 + \beta_1 Price_{1C} + \alpha_c + \varepsilon_{i1C}$$
$$u_{i2C} = \alpha_2 + \beta_2 Price_{2C} + \alpha_c + \varepsilon_{i2C}$$
$$u_{i0} = \varepsilon_{i0}$$

Product specific intercepts

Retailer preference

We observe market share s_{1Y}, s_{2Y}. Conditional on purchasing from Yihaodian,

Moment condition 1

$$\log\left(\frac{s_{1Y}}{s_{2Y}}\right) = \alpha_1 - \alpha_2 + \beta_1 Price_{1Y} - \beta_2 Price_{2Y}$$

Moment condition 2

$$\frac{s_{1Y}}{1 - s_{1Y} - s_{2Y}} = \frac{\exp(\alpha_1 + \beta_1 Price_{1Y})}{1 + \exp(\alpha_1 + \beta_1 Price_{1C} + \alpha_C) + \exp(\alpha_2 + \beta_2 Price_{2C} + \alpha_C)}$$

Moment condition 3

Bottle 1 stocks out at competitor

$$\frac{s'_{1Y}}{1 - s'_{1Y} - s'_{2Y}} = \frac{\exp(\alpha_1 + \beta_1 Price_{1Y})}{1 + \exp(\alpha_2 + \beta_2 Price_{2C} + \alpha_C)}$$

How Does It Work?

How Does It Work?

Estimation Results

SKU specific price elasticity

Degree of price shopping (0~1) 0.7911***

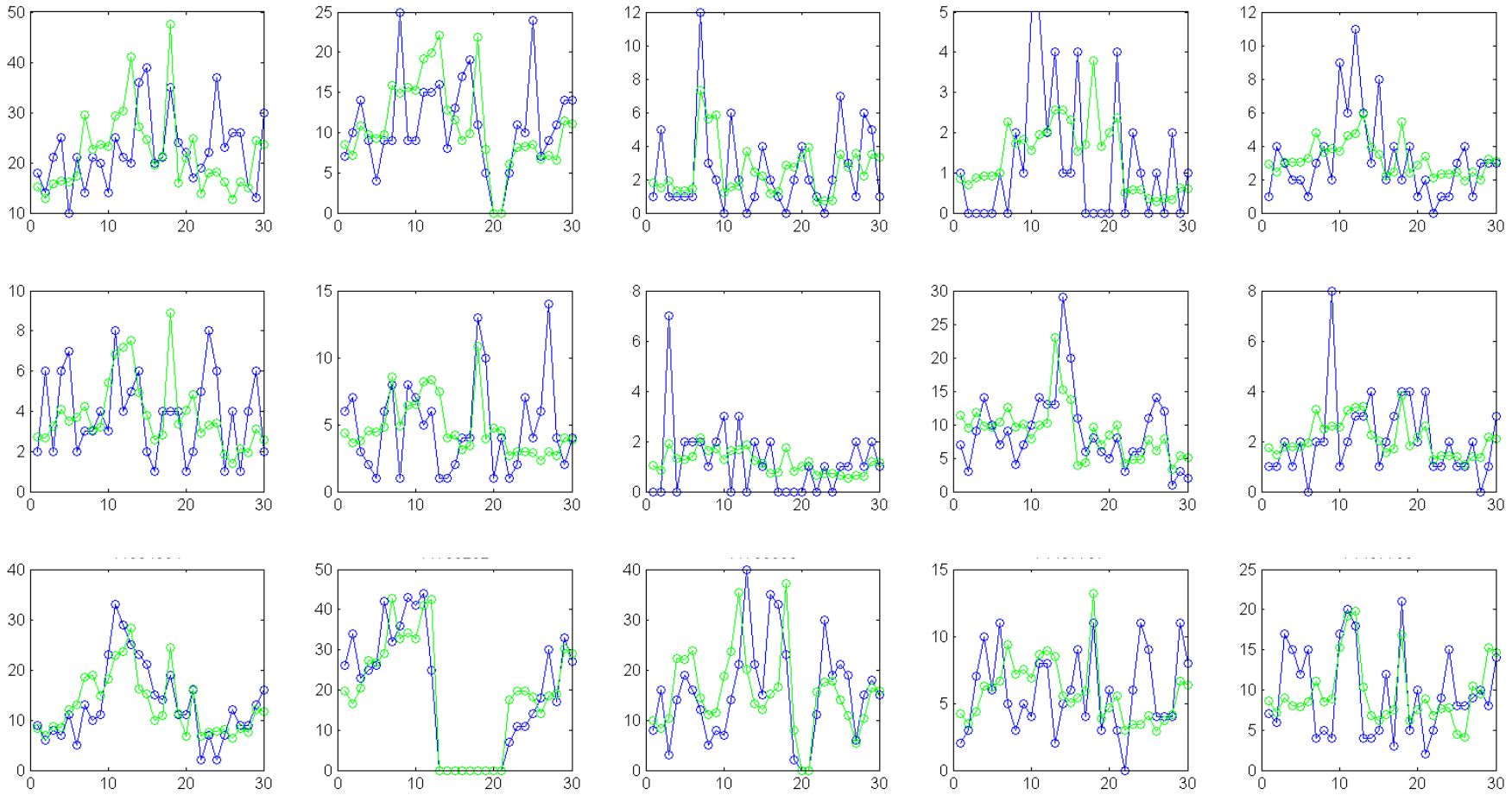
-1.6747***
-0.3667***
-6.7734***
-0.0036
-0.9532
-1.0537***
-0.5404***
-1.1644***
-1.1176***
-4.1492***
-0.5038***
-2.1872***
-11.281***
-0.9216***
-1.1421***

$$D_{jt} = \frac{\left(\frac{\alpha_j + \beta_j \log p_{jt}}{1-\lambda}\right)\left(\sum_r z_{jrt}\exp\left(\frac{\alpha_j + \alpha_r + \beta_j \log p_{jrt}}{1-\lambda}\right)\right)^{-\lambda}}{\exp(X_{0t}\gamma) + \sum_{krt}\exp\left(\frac{\alpha_j + \alpha_r + \beta_j \log p_{krt}}{1-\lambda}\right)\left(\sum_r z_{krt}\exp\left(\frac{\alpha_k + \alpha_r + \beta_j \log p_{krt}}{1-\lambda}\right)\right)^{-\lambda}} M_j$$

Consumer preference of retailer r

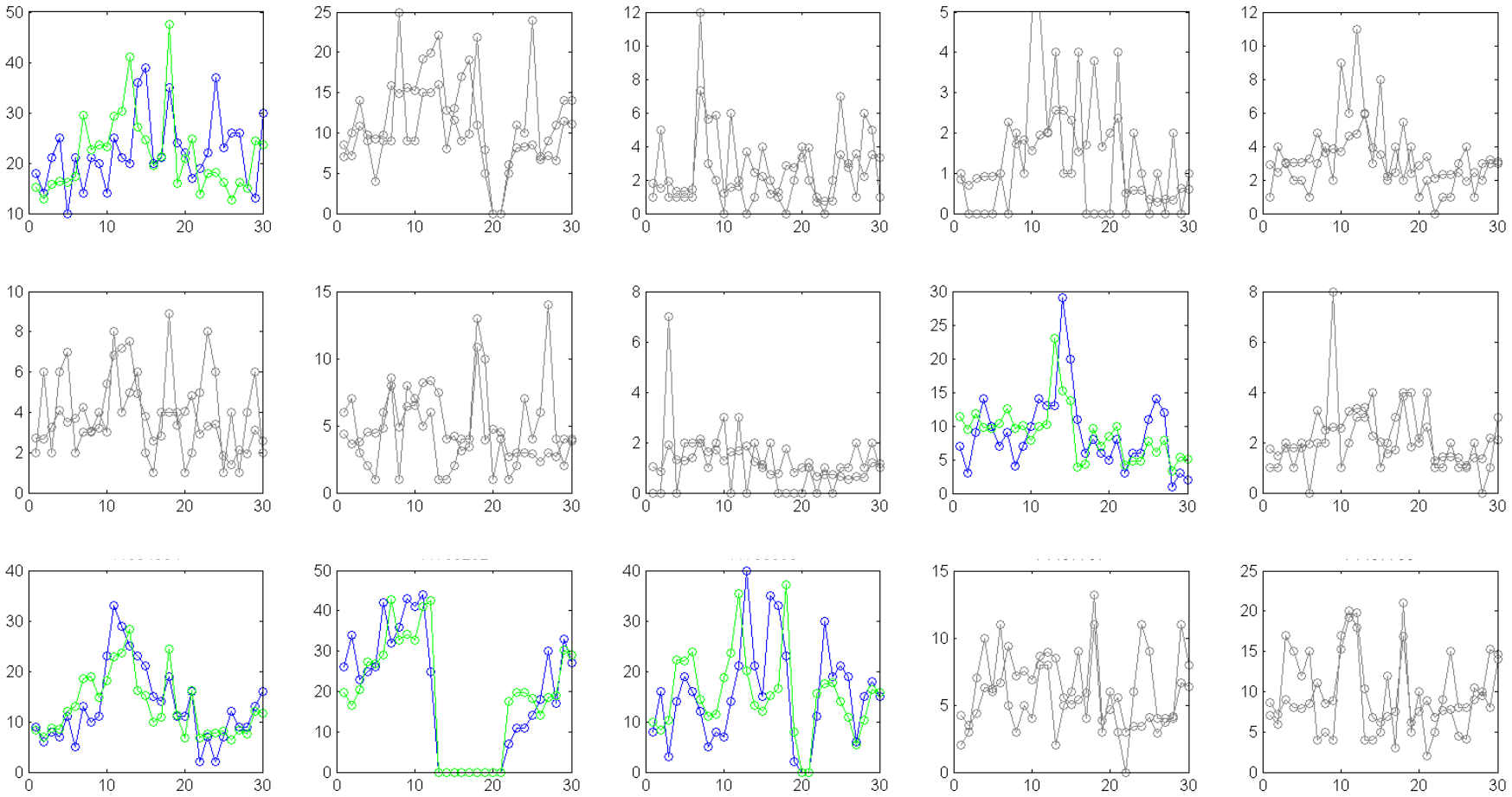
Yihaodian	Reference
Competitor 1	0.2172
Competitor 2	0.0169
Competitor 3	-1.8363***
Competitor 4	-2.4642**

Goodness of Fit



Average MAD 37.7%

Goodness of Fit

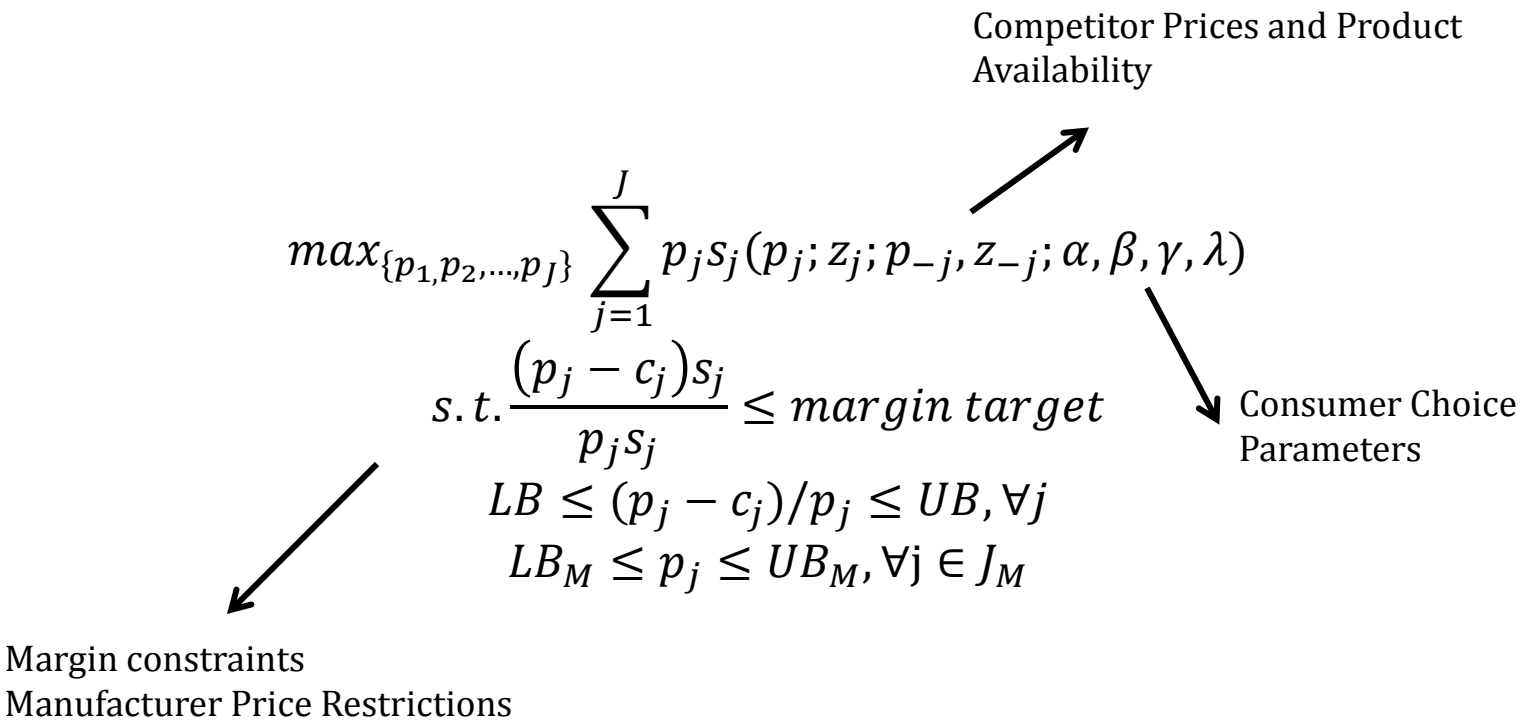


Fast Moving SKU 26.1%

Own and Cross Price Elasticity

PRODUCT	Own	Competitor 1	Competitor 2	Competitor 3	Competitor 4
1	-5.5378	-1.2071	-2.8775	-0.0055	-0.0001
2	-1.7681	-0.7598	-0.6386	-0.0012	0.0000
3	-5.4942	-0.0018	-0.0095	-0.0120	-0.0001
4	-0.0046	-0.0093	-0.0069	0.0000	0.0000
5	-1.5826	-0.4744	-0.7552	-0.0013	0.0000
6	-2.5504	-0.7253	-1.2292	-0.0020	-0.0001
7	-0.9213	-0.4088	-0.3209	-0.0006	0.0000
8	-3.6766	-1.8118	-1.0456	-0.0068	0.0000
9	-3.4141	-0.8532	-1.7617	-0.0023	-0.0001
10	-1.8954	-0.0883	-0.0164	-0.0069	0.0000
11	-2.4377	-0.9699	-0.9174	-0.0023	-0.0001
12	-8.2826	-1.5770	-4.9116	-0.0064	0.0000
13	-23.6245	-0.0152	-14.2382	-0.0138	-0.0022
14	-3.3974	-1.6779	-0.9875	-0.0051	-0.0001
15	-4.1404	-1.3791	-1.6345	-0.0094	-0.0001

Algorithm for Best Response Pricing



Pilot Test with Controlled Experiment

Treatment

Control

$

$$$

Pilot Test with Controlled Experiment

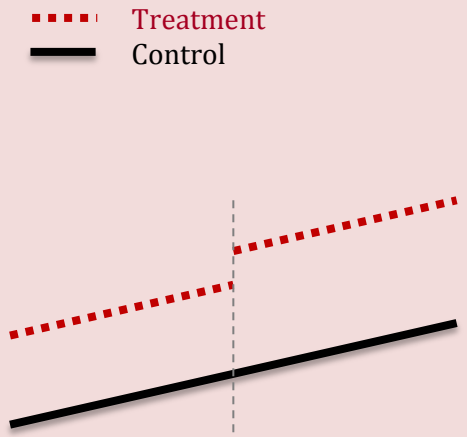
0-6 months

Above 7 months

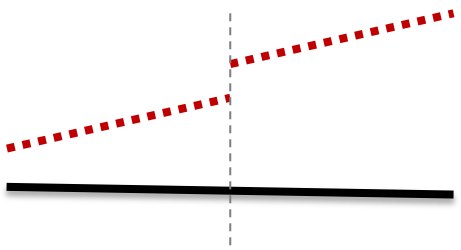
	Group 1 (baby age: 0-6months)	Group 2 (baby age: 7 months and above)
Week 0	Control	Control
Week 1	Treatment	Control
Week 2	Control	Treatment
Week 3	Treatment	Treatment
Week 4	Control	Control

Control: current pricing practice. Treatment: implement best response pricing algorithm.

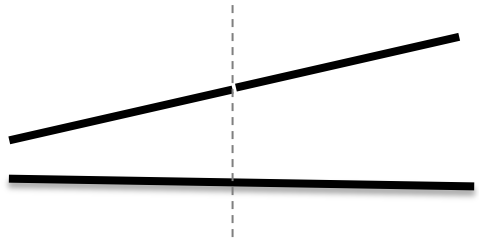
Performance Evaluation



Difference in Differences



Region A



Region B

Triple Difference Estimator

Revenue Up by 11%+, while Margin Unchanged

Sales up by 11%
Margin unchanged

Sales up by 19%
Margin unchanged

INFORMS Revenue Management
& Pricing Section Conference
Columbia Business School

Competition-Based Dynamic Pricing in Online Retailing

Marshall Fisher (The Wharton School)
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Jun Li (Ross School of Business)

Jerry Liu (Head of Pricing and Category Management, Yihaodian)
Gang Yu (Co-Founder and Chairman, Yihaodian)

2015

Executive Summary

Intellectual Merit

- Design and estimate a choice model that accounts for choices among substitutable products from multiple retailers.
- Introduce price variation through a randomized price experiment, while addressing endogeneity concerns.
- Deploy a novel identification strategy through stock-outs in the absence of competitor sales data.

Practical Impacts

- Accurate competitive response driven by deep understanding of competitors and consumers.
- Documented 11%+ revenue increase.
- Integrated with Yihaodian's IT system, and being rolled out to other categories.
- Further collaboration: EDLP and Lo/Hi pricing for FMCG products.

Fisher, M., Gallino, S. and Li, J. 2015. Competition-Based Dynamic Pricing in Online Retailing: A Methodology Validated with Field Experiments. Revise and resubmit at *Management Science*. Available at SSRN: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2547793