Pricing Patterns over Product Life-Cycle and Quality Growth at Product Turnover*

— Empirical Evidence from Japan —

Meeting of the Group of Experts on Consumer Price Indices held in Geneva, Switzerland
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* The original paper (Abe, Ito, Munakata, Ohyama, and Shinozaki (2016)) will be released as a Bank of Japan Working Paper soon.
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I. Introduction
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- The price index is constructed by indexing the price of representative goods and services with the price at the base point in time as 100.
- If a representative product shifts from the old product to the new one, the target product for the price survey is changed without delay.
- If there is a difference in quality between products, the index reflects the residue after subtracting the price difference due to the difference in quality from the whole price difference (quality adjustment).
- The whole price difference can be decomposed of the price difference due to the improvement in the new product's quality (quality growth) and the pure price increase intended to ensure the profitability (quality-adjusted price increase).
I. Introduction

- In this paper, targeting at individual products included in popular 20 commodities of durable consumer goods sold in Japan, we measure
  - **Pricing patterns**: How the price of a product changes over its product life-cycle?
  - **Quality improvement ratio (QIR)**: How much the quality growth of a new product explains the price difference?

- In the analysis, we use large data sets with 5.6 million cases which are stored by *Kakaku.com*, a well-known internet price comparison site in Japan.
II. Literature Survey and Discussions
II. Literature Survey and Discussions

(1) The Boskin Commission Report

- The issue on how the decomposition should be done in practice has been discussed among practitioners and researchers.

- The Boskin Commission Report is a representative example for such discussions.

The report criticized that BLS often compares the price difference between new products and old products directly, thus BLS underestimates the quality improvement part.

BLS and some economists responded that if we link new products and old products in a way that the price index is not be changed when firms are raising pure prices, we overestimate the quality improvement part.
II. Literature Survey and Discussions

(2) Price Setting Behavior of Firms

- Why firms tend to increase quality-adjusted prices when launching new products?
  - The firms' behavior to raise prices at the time of launching new products and the patterns of prices following the decreasing trend after the launch can be interpreted as a consequence of inter-temporal price discrimination.
  - Firms have an incentive to set the price of a new product higher than the one appropriate for its quality.
  - Then firms gradually reduce the price in line with the majority of consumers' willingness to pay.
II. Literature Survey and Discussions

(2) Price Setting Behavior of Firms

- Even the most recent research results have not yet solved the controversy on the degree of measurement errors in price indices.

Consumers with relatively high income are quicker in purchasing new models of cars. If such patterns are not taken into consideration, quality growth could be **overestimated**.

Aizcorbe, Bridgman, and Nalewaik (2010), *EL*

Shown similar results by observing firm's price setting behavior in the U.S. camcorders market.

Gowrisankaran and Rysman (2012), *JPE*

On average, most price differences between new products and old products are due to quality growth. BLS rather **underestimates** quality improvement.

Bils (2009), *QJE*
III. Empirical Analysis
III. Empirical Analysis
(1) Overview

- Expected results:
  - The pricing patterns of products follow a decreasing slope.
  - QIR is expected not to take extreme values such as 0% or 100% but rather some values in between them (e.g., 50%).

- The procedures of empirical analysis:
  1. Estimate hedonic functions by using product prices as explained variable, while by using product characteristics (specifications) and dummies as explanatory variables.
  2. Plot estimates of dummies to draw average pricing patterns.
  3. Select “matched pairs” of products.
  4. Measure QIR by dividing quality difference by price difference.
III. Empirical Analysis
(2) Data Sets

- Develop the unbalanced panel data sets by integrating the following:
  1. **Product specifications**: registered at the *Kakaku.com* between December 2012 and December 2015.
  2. **Weekly average prices**: registered at the paid *Kakaku.com Trend Search* between December 2013 and December 2015.

- **Coverage:**
  - Home electrical appliances: 8 commodities
  - Digital consumer electronics: 12 commodities

- **Data Volume:**
  - Number of products: 4,500
  - Size of panel data: 150,000
  - Total data volume: 5.6 million
Website of Kakaku.com (http://kakaku.com/)

Service Overview described by Kakaku.com, Inc.

“Purchase support service, Kakaku.com

Kakaku.com provides a wide range of information on prices, specifications, and word-of-mouth reviews of various products and services, such as computers, home appliances, internet service providers, insurance, food/beverages and cosmetics.”
The way data stored in *Kakaku.com* (e.g., Sony BRAVIA LCD TVs) 

Let's focus our attention on this product (BRAVIA KJ-40W700C) as an example.
### Detailed information with regard to the Sony BRAVIA KJ-40W700C
(Prices of the product offered by each store)

<table>
<thead>
<tr>
<th>優先順位</th>
<th>價格（日元）</th>
<th>返金可能</th>
<th>安心の保証</th>
<th>地域</th>
<th>ショップ/評価/支払方法</th>
<th>コメント</th>
<th>ショップサイト</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (6)</td>
<td>¥63,200</td>
<td>有</td>
<td>有</td>
<td>北海道</td>
<td>クレジットカード</td>
<td>保証1年</td>
<td>Shop1</td>
</tr>
<tr>
<td>2 (4)</td>
<td>¥63,300</td>
<td>有</td>
<td>有</td>
<td>神奈川</td>
<td>クレジットカード</td>
<td>保証1年</td>
<td>Shop1</td>
</tr>
<tr>
<td>3 (3)</td>
<td>¥63,500</td>
<td>有</td>
<td>有</td>
<td>東京</td>
<td>クレジットカード</td>
<td>保証1年</td>
<td>Shop1</td>
</tr>
<tr>
<td>3 (3)</td>
<td>¥63,500</td>
<td>有</td>
<td>有</td>
<td>埼玉</td>
<td>クレジットカード</td>
<td>保証1年</td>
<td>Shop1</td>
</tr>
<tr>
<td>4 (3)</td>
<td>¥64,500</td>
<td>有</td>
<td>有</td>
<td>東京</td>
<td>クレジットカード</td>
<td>保証1年</td>
<td>Shop1</td>
</tr>
<tr>
<td>5 (2)</td>
<td>¥64,500</td>
<td>有</td>
<td>有</td>
<td>広島</td>
<td>クレジットカード</td>
<td>保証1年</td>
<td>Shop1</td>
</tr>
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<td>5 (2)</td>
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<td>愛知</td>
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<td>6 (2)</td>
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<td>有</td>
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<td>Shop1</td>
</tr>
<tr>
<td>6 (2)</td>
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<td>有</td>
<td>有</td>
<td>東京</td>
<td>クレジットカード</td>
<td>保証1年</td>
<td>Shop1</td>
</tr>
</tbody>
</table>

### Specifications of the product

<table>
<thead>
<tr>
<th>表示性能</th>
<th>画面サイズ [新規]</th>
<th>画素数 [新規]</th>
<th>1920x1080</th>
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</thead>
<tbody>
<tr>
<td>LEDバックライト</td>
<td>LEDバックライト</td>
<td>4K [新規]</td>
<td></td>
</tr>
<tr>
<td>フルハイビジョン [新規]</td>
<td>○</td>
<td>3Dテレビ</td>
<td></td>
</tr>
<tr>
<td>エントランス</td>
<td>落下防止</td>
<td>感度</td>
<td>应答速度</td>
</tr>
<tr>
<td>画面分割</td>
<td>○</td>
<td>1インチあたりの価格</td>
<td>¥1,580</td>
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<table>
<thead>
<tr>
<th>チューナー</th>
<th>デジタルチューナー内蔵</th>
<th>地上S/110</th>
</tr>
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<tbody>
<tr>
<td>チューナーセパレート</td>
<td>4K放送対応チューナー (スカパーのみ)</td>
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</tr>
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</table>

<table>
<thead>
<tr>
<th>録画再生機能</th>
<th>外付けHDD</th>
<th>再生機能</th>
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</thead>
<tbody>
<tr>
<td>無線端子</td>
<td>HOME鎮子</td>
<td>4端子</td>
</tr>
<tr>
<td></td>
<td>ARC対応</td>
<td>ARC端子</td>
</tr>
<tr>
<td></td>
<td>HDMI対応</td>
<td>D5端子</td>
</tr>
<tr>
<td></td>
<td>USB端子</td>
<td>コンポーネント</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>ネットワーク</th>
<th>LAN端子</th>
<th>WiFi端子</th>
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</thead>
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<tr>
<td></td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td></td>
<td>DLNA → DLNA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wi-Fi Direct端子</td>
<td>Wi-Fi Direct端子</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>基本仕様</th>
<th>カードスロット</th>
<th>別売</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>壁掛け対応</td>
<td>別売</td>
</tr>
<tr>
<td></td>
<td>消費電力</td>
<td>71 W</td>
</tr>
<tr>
<td></td>
<td>送電時電力</td>
<td>0.5 W</td>
</tr>
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<table>
<thead>
<tr>
<th>サイズ重量</th>
<th>幅</th>
<th>深さ</th>
<th>厚さ</th>
<th>924x570x179 mm</th>
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<tbody>
<tr>
<td></td>
<td>重量</td>
<td>9.1 kg</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| 省エネ性能 | |
|----------|
III. Empirical Analysis

(3) Estimation of Hedonic Functions

- We estimate the following **semi-logarithmic hedonic functions** with a dummy variable to control the elapse of time from the launch of products to capture the price transition through the product life-cycle.

\[
\ln(p_{i,t}) = \alpha + \sum_k \beta_k X_{i,k} + \sum_\tau \gamma_\tau D_t(\tau_i + \tau) + \sum_\tau \delta_\tau D_t(\tau) + \varepsilon_{i,t}
\]

\[
D_t(T) = \begin{cases} 
1 & \text{if } t = T \\
0 & \text{if } t \neq T
\end{cases}
\]

- LSDV (Least Square Dummy Variables) estimation with White robust standard errors has been applied.
III. Empirical Analysis

(4) Measurement of Pricing Patterns

- We plot the coefficient estimates of week dummy variables with exponential transformation \( \exp(\hat{\gamma}) \) as time proceeds.

- The price of products tends to decrease and the pace of decrease becomes moderate with the elapse of time from the launch.

- Generally speaking, the pure price increase of home electrical appliances is somewhat larger than that of digital consumer electronics, while the pace of price decrease of home appliances also tends to be faster.

  —— Regarding home electrical appliances, price competition over quantifiable quality could be more lenient than digital consumer electronics. Consumers might value home appliances more at other elements than quantifiable quality (e.g., design of products, the product image incurred by advertisement, etc.)
Pricing Patterns over Product Life-Cycle: Home Electrical Appliances

(1) Air conditioners

(2) Refrigerators and freezers

(3) Washers and dryers

(4) Rice cookers

(5) Vacuum cleaners

(6) Microwaves

(7) Hair dryers and curling irons

(8) Air purifiers
Pricing Patterns over Product Life-Cycle: Digital Consumer Electronics

(1) GPS navigations
(2) External hard drives
(3) LCD TVs
(4) LCD monitors
(5) Printers
(6) Blu-ray and DVD recorders
(7) Headphones
(8) Camcorders
(9) Laptops
(10) Desktops
(11) Point-and-shoot cameras
(12) DSLR and mirrorless cameras
III. Empirical Analysis

(5) Selection of Matched Pairs of Products

(Selection Criteria of Matched Pairs of Products)

1. The launch date of a new product is later than that of the old product
2. New products and old products are made by the same manufacturer
3. The price of a new product on the launch date is higher than that of the old product on the same day
4. The quality of the new product is better than that of the old product

Based on the above criteria, it is impossible to eliminate pairs of new products and old products which belong to different line-ups (e.g., a pair of "low-end old model" and "high-end new model"). In order to eliminate such an inappropriate matching, we establish two additional criteria of using (1) **Relative Difference in Quality** and (2) **Levenshtein Distance**, and conduct further analysis. However, the conclusions differ very little regardless of which approach is used (see Appendix of the paper).
III. Empirical Analysis

(6) Measurement of Quality Growth

- Based on the matched pairs of products, we measure the QIR of individual pairs, and examine the shapes of QIR distributions. QIR is

\[ \mu_{i,j}^{\tau} \equiv \sum_{k} \beta_k (X_{j,k} - X_{i,k}) \]

\[ \ln \left( \frac{p_{j,\tau + \tau}}{p_{i,\tau + \tau}} \right) \]

- We calculate the QIR for each pair and demonstrate their histogram by the continuous function (kernel density function).
Distribution of Quality Improvement Ratios: Overview

(1) Home electrical appliances

- The number of pairs of products: 3,204

(2) Digital consumer electronics

- The number of pairs of products: 11,662
Distribution of Quality Improvement Ratios: Home Electrical Appliances

(1) Air conditioners

The number of pairs of products: 1,050

(2) Refrigerators and freezers

The number of pairs of products: 422

(3) Washers and dryers

The number of pairs of products: 276

(4) Rice cookers

The number of pairs of products: 605

(5) Vacuum cleaners

The number of pairs of products: 130

(6) Microwaves

The number of pairs of products: 260

(7) Hair dryers and curling irons

The number of pairs of products: 257

(8) Air purifiers

The number of pairs of products: 204
Distribution of Quality Improvement Ratios: Digital Consumer Electronics

(1) GPS navigations
The number of pairs of products: 285

(2) External hard drives
The number of pairs of products: 1,952

(3) LCD TVs
The number of pairs of products: 798

(4) LCD monitors
The number of pairs of products: 497

(5) Printers
The number of pairs of products: 129

(6) Blu-ray and DVD recorders
The number of pairs of products: 1,278

(7) Headphones
The number of pairs of products: 1,298

(8) Camcorders
The number of pairs of products: 62

(9) Laptops
The number of pairs of products: 2,931

(10) Desktops
The number of pairs of products: 675

(11) Point-and-shoot cameras
The number of pairs of products: 529

(12) DSLR and mirrorless cameras
The number of pairs of products: 537
IV. Concluding Remarks
IV. Concluding Remarks

(1) Key Findings

- Pure price increases, intended to ensure the profitability when launching a new product; are widely observed both for home electrical appliances and digital consumer electronics.

- The pace of price decrease becomes moderate as time proceeds.

- Home electrical appliances has a somewhat larger degree of pure price increase and a somewhat faster pace of price fall afterwards, compared to digital consumer electronics.

- QIR depicts a unimodal distribution fat-tailed slightly to the right for both home electrical appliances and digital consumer electronics.

- Mode value of the distribution measured immediately after the launch indicates about 0.5-0.6 for home electrical appliances and about 0.6-0.7 for digital consumer electronics.
IV. Concluding Remarks

(2) Implications for Quality Adjustment Methods

- Some price statistics agencies have used a simple method to regard
  50% of the price difference between new and old products as the
  quality improvement part if its magnitude is not known (so-called
  50% rule)
  - In Netherlands (Hoven (1999))
  - In Sweden (Dalen and Tarassiouk (2013))
  - In Germany, prior to 1997 (Hoffmann (1999))

- In the past, Ohta (1977) has proposed to use the 50% based on the
  principle of risk minimization under uncertainty if we do not know
  the qualities of products well.
IV. Concluding Remarks
(2) Implications for Quality Adjustment Methods

- The 50% rule has not been sufficiently supported either theoretically or in practice.
- The results of the paper support the appropriateness of the 50% rule as a second-best solution which is easy to adopt even under severe resource constraints and contributes to improving the precision of the price index.

The Bank of Japan has announced the rebasing of the PPI by updating the base year from 2010 to 2015. Taking that opportunity, the Bank plans to introduce a new quality adjustment method for some durable consumer goods based on the thinking of the 50% rule as a second-best measure.