Effects of New Goods and Product Turnover on Price Indexes

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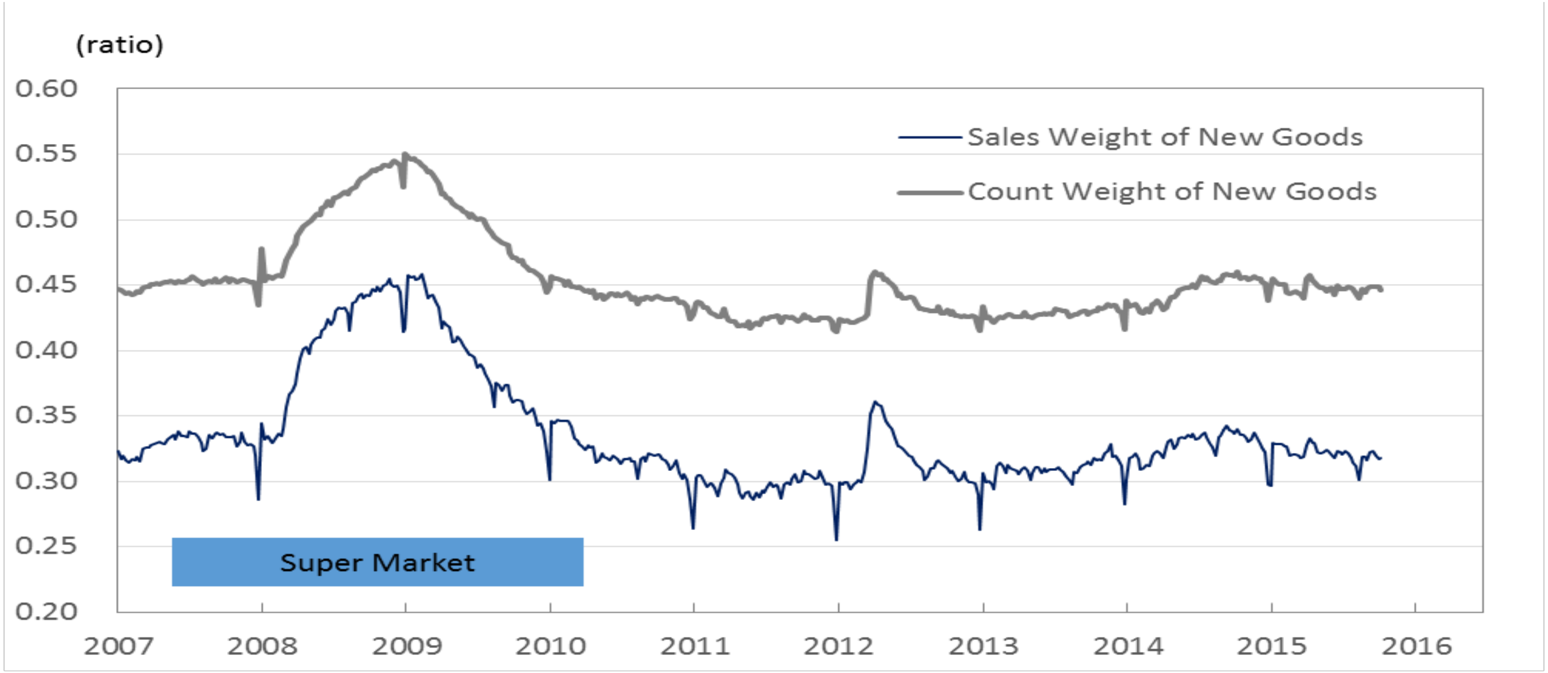
INTRODUCTION

Background

- The treatment of new products is a central issue in constructing price indexes
- New products are introduced into markets almost daily, and a number of goods disappear almost daily, too
- However, most economic indicators of prices, such as official consumer price indexes (CPIs) are based on fixed bundles of commodities.
- That is, most newly introduced goods are neglected in many official statistics unless the new products occupy significant market share.

Point (1): Importance of Product Turnover

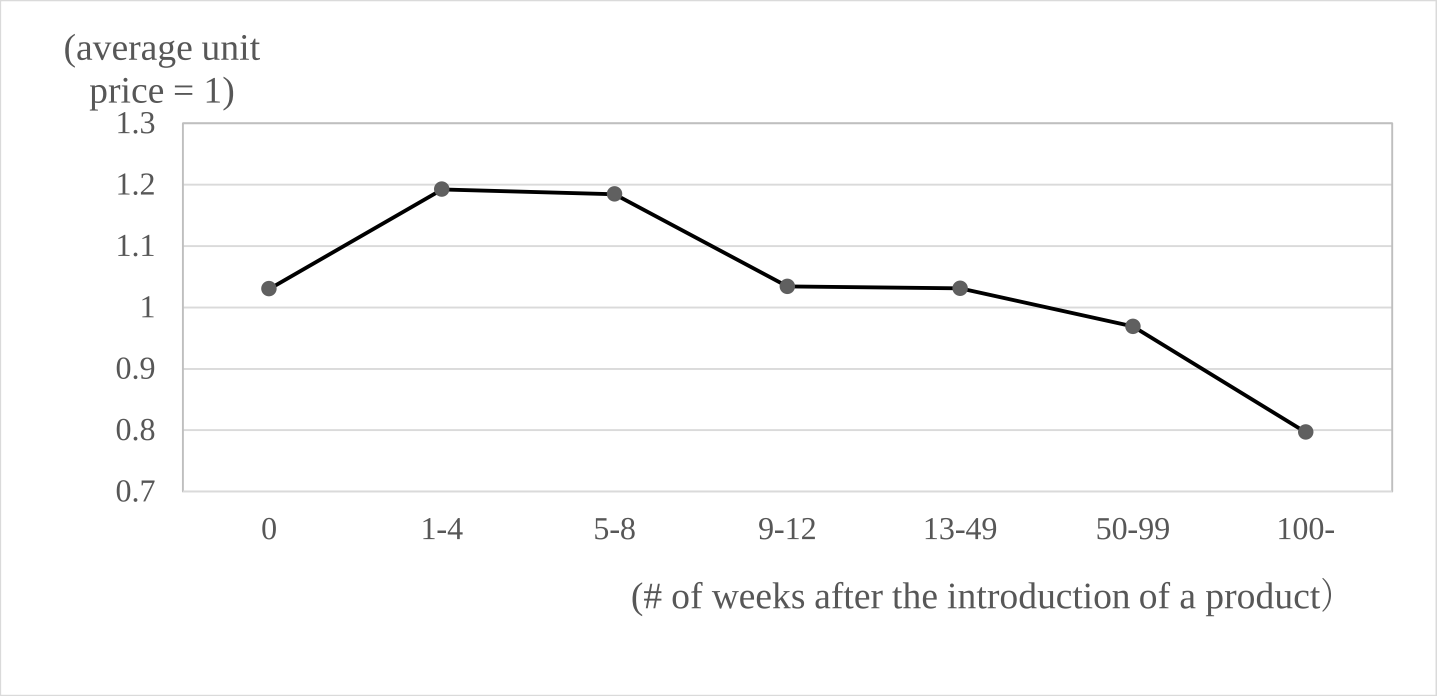


Notes: We define new goods as those sold in the current period but not during the same week 1 year earlier. “Share of New Goods (Sales)” is the share of new goods sales to total sales at a store in a week. “Share of New Goods (Number of Items)” is the share of the number of new goods items to the number of total items at a store in a week. When constructing shares, we calculate the shares at store level, and then, aggregate them over stores.

Point (2): Product Aging and Pricing Pattern

- If prices of new goods are not so different from old or incumbent goods, very frequently product turnover might not be a serious problem in measuring CPI.
- But, this is not the case.
- New products tend to be priced higher than incumbent goods.

Difference in Unit Prices of New and Incumbent Cup Noodles



Note: The relative price of items is classified as cup noodles traded from September 2012 to December 2014. The horizontal axis shows the number of weeks that have passed after the introduction of the items. The vertical axis is the relative price of the items. The average price normalizes at unity. Relatively low prices in week 0 might reflect bargain sales to promote new goods.

Research Purpose

- Based on a CES utility function, Feenstra (1994) and Feenstra and Shapiro (2003) derive a formula for a true COLI that captures the welfare effects of variety expansion.
- Broda and Weinstein (2010), also using the CES utility function, find that new goods cause significant “bias” in the price index
- Our study is in line with those previous studies
- However, in this study, rather than the effects of variety expansion, we focus on the price differentials between new products and incumbent products
- That is, we attempt to capture the effects of product turnover even if the total variety is constant

Our Contributions

- We extend the decomposition technique of **unit value price index (UVPI)** developed by Silver (2009, 2010) and Diewert and von der Lippe (2010)
- The technique decompose the UVPI into three effects: (1) **price change effects**, (2) **substitution effects**, and (3) **product turnover effects**
- We calculate the **UVPI** and **COLIs with product variety based on POS data** to compare them.
- **Significant discrepancies between the UVPI and the COLIs** emerged through the introduction of relatively more expensive goods during the period 2007 and 2008 and the period after 2014

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COST OF LIVING INDEX WITH PRODUCT TURNOVER

COLI with Product Turnover

- **Sato** (1976) and **Vartia** (1976): COLI based on CES Utility Function without Product Turnover
- **Feenstra** (1994): Sato-Vartia COLI with **Product Variety Effect**
- **Broda and Weinstein** (2010): Sato-Vartia COLI with **Product and Brand Variety Effects**

Sato-Vartia COLI

- We specify the upper level CES utility function as follows:

$$U_t = \left(\sum_{g_t \in G} \beta_g \left(C_t^g \right)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

  - C_t^g is the aggregate consumption of product group $g_t \in G$
  - G is the set of all product groups.
  - β_g is the weight of category g in the CES utility function.
  - σ is the CES across product groups for demand
- The lower level of the utility function is

$$C_t^g = \left(\sum_{i \in g_t} \alpha_i \left(q_t^i \right)^{\frac{\sigma_g-1}{\sigma_g}} \right)^{\frac{\sigma_g}{\sigma_g-1}},$$

  - q_t^i is the consumption quantity of individual goods index $i \in g_t$
  - α_i is the weight of goods i in the CES aggregator
  - σ_g is the CES within product group g_{t} for demand.

Sato-Vartia COLI

- The unit cost function of C_t^g as follows:

$$\frac{E(p_t, g_t)}{C_t^g} = \left(\sum_{i \in g_t} \alpha_i^{\sigma} \left(p_t^i\right)^{1-\sigma_g}\right)^{\frac{1}{1-\sigma_g}}$$

  - p_t is the vector of individual prices and p_t^i is the price of the individual goods index $i \in g_t$
- The COLI of product group g can be written as

$$COLI\left(p_t, p_{t-y}, g_t, g_{t-y}\right) = \frac{E(p_t, g_t)}{E(p_{t-y}, g_{t-y})}$$

- Sato (1976) and Vartia (1976) show that the above COLI can be calculated without estimating the values of α_i and σ_g, if the sets of individual products are the same between the current and base period, that is, if $g_t = g_{t-y} = g$

Sato-Vartia COLI

- The exact price index of group g, $PI_{SV}(p_t, p_{t-y}, g)$, can be formulated as follows:

$$PI_{SV}(p_t, p_{,t-y}, g) = \frac{E(p_t, g)}{E(p_{t-y}, g)} = \prod_{i \in g} \left(\frac{p_t^i}{p_{t-y}^i} \right)^{\phi_t^i(g)}$$

  - Where $\phi_t^i(g) = \left(\frac{w_t^i(g) - w_{t-y}^i(g)}{\ln\left(w_t^i(g)\right) - \ln\left(w_{t-y}^i(g)\right)} \right) \Big/ \left(\sum_{i \in g} \left(\frac{w_t^i(g) - w_{t-y}^i(g)}{\ln\left(w_t^i(g)\right) - \ln\left(w_{t-y}^i(g)\right)} \right) \right)$ and $w_t^i(g) = \frac{p_t^i q_t^i}{\sum_{i \in g} p_t^i q_t^i}$

- It is possible to obtain the aggregate-level Sato–Vartia-type COLI, PI_t^{SV} , as follows:

$$PI_t^{\mathrm{SV}} = \prod_{g \in G} \left[PI_{SV}(p_t, p_{t-y}, g_{t,t-y}) \right]^{\phi_t^g}$$

  - where $\phi_t^g = \left(\frac{w_t^g - w_{t-y}^g}{\ln(w_t^g) - \ln\left(w_{t-y}^g\right)} \right) \Big/ \left(\sum_{g \in G} \left(\frac{w_t^g - w_{t-y}^g}{\ln(w_t^g) - \ln\left(w_{t-y}^g\right)} \right) \right)$ where $w_t^g = \frac{\sum_{i \in g_{t,t-y}} p_t^i q_t^i}{\sum_{g \in G} \sum_{i \in g_{t,t-y}} p_t^i q_t^i}$

Feenstra COLI

- Feenstra (1994) develops the concept of the COLI for the case in which sets of individual products are not the same between the current period and the base period, that is, $g_t \neq g_{t-y}$
- Feenstra's COLI , $P_F\left(p_t, p_{t-y}, g_t, g_{t-y}\right)$,is defined as follows:

$$P_F\left(p_t, p_{t-y}, g_t, g_{t-y}\right) = \frac{E\left(p_t, g_t\right)}{E\left(p_{t-y}, g_{t-y}\right)} = PI_{SV}^{g}\left(p_t, p_{t-y}, g_{t,t-y}\right)\left(\frac{\lambda_{gt}^{\mathrm{cr}}}{\lambda_{gt}^{\mathrm{bs}}}\right)^{\frac{1}{\sigma_g - 1}}$$

  - where $g_{t,t-y} = g_t \cap g_{t-y}$, and $\lambda_{gt}^{\mathrm{cr}} = \frac{\sum_{i \in g_{t,t-y}} p_t^i q_t^i}{\sum_{i \in g_t} p_t^i q_t^i}$, $\lambda_{gt}^{\mathrm{bs}} = \frac{\sum_{i \in g_{t,t-y}} p_{t-y}^i q_{t-y}^i}{\sum_{i \in g_{t-y}} p_{t-y}^i q_{t-y}^i}$
  - The term $\left(\lambda_{gt}^{\mathrm{cr}} / \lambda_{gt}^{\mathrm{bs}}\right)^{\frac{1}{\sigma_g - 1}}$, which is known as the group-level lambda ratio adjusted by σ_g
- The aggregate-level COLI based on Feenstra (1994), PI_t^{F}, are given by following expression:

$$PI_t^{\mathrm{F}} = \prod_{g \in G}\left[PI_{SV}\left(p_t, p_{t-y}, g_{t,t-y}\right)\left(\frac{\lambda_{gt}^{\mathrm{cr}}}{\lambda_{gt}^{\mathrm{bs}}}\right)^{\frac{1}{\sigma_g - 1}}\right]^{\phi_t^g}$$

- It is required to estimate the elasticity of substitution for demand within a group

Broda-Weinstein COLI

- Based on Feenstra (1994), Broda and Weinstein (2010) extend the COLI by taking account of within-brand variety and across-brand variety in the COLI
- Here, the COLI has three layers: brand-level, product group-level, and aggregate-level
- The aggregate-level COLI based on Broda and Weinstein (2010), PI_t^{BW}, are as follows:

$$PI_t^{\mathrm{BW}} = \prod_{g \in G} \left\{ \prod_{b \in g} \left[PI_{SV}(p_t, p_{t-y}, b_{t,t-y}) \left(\frac{\lambda_{bt}^{\mathrm{cr}}}{\lambda_{bt}^{\mathrm{bs}}} \right)^{\frac{1}{\sigma_b - 1}} \right]^{\phi_t^b} \left(\frac{\lambda_{gt}^{\mathrm{cr}}}{\lambda_{gt}^{\mathrm{bs}}} \right)^{\frac{1}{\sigma_g - 1}} \right\}^{\phi_t^g}$$

- where b_t is a set of brands change over time, $b_t \in g_t$
- σ_b is substitution elasticity of demand within a brand b_t
- σ_g is the substitution elasticity of demand across brands in a group g_t

Broda-Weinstein COLI

- $\lambda_{bt}^{\text{cr}}, \lambda_{bt}^{\text{bs}}, \lambda_{gt}^{\text{cr}}$, and λ_{gt}^{bs} are defined as follows:

$$\lambda_{bt}^{\text{cr}} = \frac{\sum_{i\in b_{t,t-y}} p_t^i q_t^i}{\sum_{i\in b_t} p_t^i q_t^i}, \qquad \lambda_{bt}^{\text{bs}} = \frac{\sum_{i\in b_{t,t-y}} p_{t-y}^i q_{t-y}^i}{\sum_{i\in b_{t-y}} p_{t-y}^i q_{t-y}^i},$$

$$\lambda_{gt}^{\text{cr}} = \frac{\sum_{b\in g_{t,t-y}} \sum_{i\in b_{t,t-y}} p_t^i q_t^i}{\sum_{b\in g_t} \sum_{i\in b_t} p_t^i q_t^i}, \qquad \lambda_{gt}^{\text{bs}} = \frac{\sum_{i\in g_{t,t-y}} \sum_{i\in b_{t,t-y}} p_{t-y}^i q_{t-y}^i}{\sum_{i\in g_{t-y}} \sum_{i\in b_{t-y}} p_{t-y}^i q_{t-y}^i}$$

- ϕ_t^b and ϕ_t^g are defined as follows:

$$\phi_t^b = \left(\frac{w_t^b - w_{t-y}^b}{\ln(w_t^b) - \ln(w_{t-y}^b)}\right) \Bigg/ \left(\sum\nolimits_{b\in g} \left(\frac{w_t^b - w_{t-y}^b}{\ln(w_t^b) - \ln(w_{t-y}^b)}\right)\right) \text{ where } w_t^b = \frac{\sum_{i\in b_{t,t-y}} p_t^i q_t^i}{\sum_{b\in g} \sum_{i\in b_{t,t-y}} p_t^i q_t^i}$$

$$\phi_t^g = \left(\frac{w_t^g - w_{t-y}^g}{\ln(w_t^g) - \ln\left(w_{t-y}^g\right)}\right) \Bigg/ \left(\sum\nolimits_{g\in G} \left(\frac{w_t^g - w_{t-y}^g}{\ln(w_t^g) - \ln\left(w_{t-y}^g\right)}\right)\right) \text{ where } w_t^g = \frac{\sum_{b\in g} \sum_{i\in b_{t,t-y}} p_t^i q_t^i}{\sum_{g\in G} \sum_{b\in g} \sum_{i\in b_{t,t-y}} p_t^i q_t^i}$$

- We need to estimate the within brand and across brand elasticities of substitution

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DECOMPOSITION OF UNIT VALUE PRICE INDEX

Assumption of Unit Value Price Index

- Under the assumption of **perfect substitution within the category**, we can measure the price level of one category as the unit value price index
- For example, a brand of **500 ml orange juice package** and **1000 ml orange juice package of the same brand are distinguished from the perspective of the Universal Product Code**, even if their contents are virtually the same
- We consider that that consumption of these two orange juice packages gives the same utility level to a consumer as the consumption of a package of **1500 ml orange juice of the brand**

Unit Value Price Index

- We assume that the utility function of the representative consumer has the following two layers:

$$U_t = \left(\sum_{g_t \in G} \beta_g \left(C_t^g \right)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}},$$

$$C_t^g = \sum_{i \in g_t} v^i q_t^i$$

  - where v^i is the volume of the product i.

- Then, the unit cost function of product group g can be written as

$$\frac{E(p_t, q_t, v, g_t)}{C_t^g} = \sum_{i \in g_t} \left(\frac{v^i q_t^i}{\sum_{i \in g_t} v^i q_t^i} \right) \frac{p_t^i}{v^i}$$

Unit Value Price Index

- The unit value price index of category g is defined as

$$PI_U(p_t, p_{t-y}, q_t, q_{t-y}, g_t, g_{t,t-y}) \equiv \left(\sum_{i \in g_t} \left(\frac{v^i q_t^i}{\sum_{i \in g_t} v^i q_t^i} \right) \frac{p_t^i}{v^i} \right) \Bigg/ \left(\sum_{i \in g_{t-y}} \left(\frac{v^i q_{t-y}^i}{\sum_{i \in g_{t-y}} v^i q_{t-y}^i} \right) \frac{p_{t-y}^i}{v^i} \right)$$

- The aggregate level COLI, PI_t^{U}, is given by the following expression:

$$PI_t^{\mathrm{U}} = \prod_{g \in G} \left[PI_U(p_t, p_{t-y}, q_t, q_{t-y}, g_t, g_{t,t-y}) \right]^{\phi_t^{gu}},$$

  - where $\phi_t^{gu} = \left(\frac{w_t^{gu} - w_{t-y}^{gu}}{\ln(w_t^{gu}) - \ln(w_{t-y}^{gu})} \right) \Bigg/ \left(\sum_{g \in G} \left(\frac{w_t^{gu} - w_{t-y}^{gu}}{\ln(w_t^{gu}) - \ln(w_{t-y}^{gu})} \right) \right)$ and $w_t^{gu} = \frac{\sum_{i \in g_t} p_t^i q_t^i}{\sum_{g \in G} \sum_{i \in g_t} p_t^i q_t^i}$

New Goods, Old Goods, and Continuing Goods

- To capture the effects of the changes in the product space, first, we classify all commodities in category g into (1) new goods, (2) old goods, and (3) continuing goods
- Consider two periods, the current period t and the base period $t - y$, where y is a fixed time interval, such as 1 year
  - A product i is defined as a "new good" in period t if the product exists in period t but not in period $t - y$.
  - A product i is defined as an "old good" in period t if the commodity does not exist in period t but exists in period $t - y$.
  - A product i is defined as a "continuing good" in period t if the commodity exists in both period t and period $t - y$
- We define g_t^N , g_t^O , and $g_{t,t-y}$ as the set of new goods, the set of old goods, and the set of continuing goods, respectively, in category g in period t

$$g_t^N = g_t \cap \overline{g_{t-y}}$$
$$g_t^O = \overline{g_t} \cap g_{t-y}$$
$$g_{t,t-y} = g_t \cap g_{t-y}$$

Note: We recognize two products which have a same JAN code as different two products, if the two products are sold at different two stores in the POS data

UVPIs for New Goods, Old Goods, and Continuing Goods

- The unit value price of category g in period t, $P_t^U(g)$, can be expressed as the weighted sum of the unit value price of continuing goods, $P_t^{UC}(g)$, and new goods, $P_t^{UN}(g)$

$$P_t^U(g) \equiv \sum_{i \in g_t} \left(\frac{v^i q_t^i}{\sum_{i \in g_t} v^i q_t^i} \right) \frac{p_t^i}{v^i}$$

$$= \left(\frac{\sum_{i \in g_{t,t-y}} v^i q_t^i}{\sum_{i \in g_t} v^i q_t^i} \right) \sum_{i \in g_{t,t-y}} \left(\frac{v^i q_t^i}{\sum_{i \in g_{t,t-y}} v^i q_t^i} \right) \frac{p_t^i}{v^i} + \left(\frac{\sum_{i \in g_t^N} v^i q_t^i}{\sum_{i \in g_t} v^i q_t^i} \right) \sum_{i \in g_t^N} \left(\frac{v^i q_t^i}{\sum_{i \in g_t^N} v^i q_t^i} \right) \frac{p_t^i}{v^i}$$

$$\equiv w_t^C(g) P_t^{UC}(g) + w_t^N(g) P_t^{UN}(g)$$

  - where

$$w_t^C(g) = \frac{\sum_{i \in g_{t,t-y}} v^i q_t^i}{\sum_{i \in g_t} v^i q_t^i}, \text{and } w_t^N(g) = \frac{\sum_{i \in g_t^N} v^i q_t^i}{\sum_{i \in g_t} v^i q_t^i}$$

UVPIs for New Goods, Old Goods, and Continuing Goods

- Similarly, we can construct the unit value price index in period $t - y$, $P^U_{t-y}(g)$, as the weighted sum of the unit value prices of continuing goods, $P^{UC}_{t-y}(g)$, and old goods, $P^{UO}_{t-y}(g)$

$$P^U_{t-y}(g) \equiv \sum_{i \in g_{t-y}} \left(\frac{v^i q^i_{t-y}}{\sum_{i \in g_{t-y}} v^i q^i_{t-y}} \right) \frac{p^i_{t-y}}{v^i}$$

$$= \left(\frac{\sum_{i \in g_{t,t-y}} v^i q^i_{t-y}}{\sum_{i \in g_{t-y}} v^i q^i_{t-y}} \right) \sum_{i \in g_{t,t-y}} \left(\frac{v^i q^i_{t-y}}{\sum_{i \in g_{t,t-y}} v^i q^i_{t-y}} \right) \frac{p^i_{t-y}}{v^i} + \left(\frac{\sum_{i \in g^O_t} v^i q^i_{t-y}}{\sum_{i \in g_{t-y}} v^i q^i_t} \right) \sum_{i \in g^O_t} \left(\frac{v^i q^i_{t-y}}{\sum_{i \in g^O_t} v^i q^i_{t-y}} \right) \frac{p^i_{t-y}}{v^i}$$

$$\equiv w^C_{t-y}(g) P^{UC}_{t-y}(g) + w^O_{t-y}(g) P^{UO}_{t-y}(g)$$

  - where

$$w^C_{t-y}(g) = \frac{\sum_{i \in g_{t,t-y}} v^i q^i_{t-y}}{\sum_{i \in g_{t-y}} v^i q^i_{t-y}}, \text{and } w^O_{t-y}(g) = \frac{\sum_{i \in g^O_t} v^i q^i_{t-y}}{\sum_{i \in g_{t-y}} v^i q^i_{t-y}}$$

Decomposition into Price Change, Substitution, and Turnover Effects

- The inflation rate of the unit price index can be written as follows:

$$PI_U\left(p_t, p_{t-y}, q_t, q_{t-y}, g_t, g_{t,t-y}\right) - 1 \equiv \frac{P_t^U(g) - P_{t-y}^U(g)}{P_{t-y}^U(g)}$$

$$= \left(\frac{P_{t-y}^{UC}(g)}{P_{t-y}^U(g)}\right) \frac{w_t^C(g) P_t^{UC}(g) - w_{t-y}^C(C) P_{t-y}^{UC}(g)}{P_{t-y}^{UC}(g)} + \left(\frac{P_{t-y}^{UO}(g)}{P_{t-y}^U(g)}\right) \frac{w_t^N(g) P_t^{UN}(g) - w_{t-y}^O(g) P_{t-y}^{UO}(g)}{P_{t-y}^{UO}(g)}$$

Decomposition into Price Change, Substitution, and Turnover Effects

- The UVPI can be decomposed into three factors as follows:

$$PI_U\left(p_t, p_{t-y}, q_t, q_{t-y}, g_t, g_{t,t-y}\right) - 1 = \left(\frac{P^{UC}_{t-y}(g)}{P^{U}_{t-y}(g)}\right) w^{C}_{t-y}(g)\pi^{LC}_t(g) + \left(\frac{P^{UC}_{t-y}(g)}{P^{U}_{t-y}(g)}\right) w^{C}_{t-y}(g)\phi^{UC}_t(g)$$

Price Change Effect — Substitution Effect

$$+\frac{w^{O}_{t-y}(g)\left(P^{UC}_t(g) - P^{UO}_{t-y}(g)\right) + w^{N}_t(g)(P^{UN}_t(g) - P^{UC}_t(g))}{P^{U}_{t-y}(g)} + \left(\frac{P^{UC}_{t-y}(g)}{P^{U}_{t-y}(g)}\right) w^{C}_{t-y}(g)\phi^{UC}_t(g)\pi^{UC}_t(g)$$

Price Change Effect — Cross Term

- where
  - $\pi^{LC}_t = \frac{\sum_{i\in g_{t,t-y}}[q^i_{t-y}p^i_t]}{\sum_{i\in g_{t,t-y}}\left[q^i_{t-y}p^i_{t-y}\right]} - 1$
  - $\phi^{UC}_t(g) = \frac{\sum_{i\in g_{t,t-y}} p^i_t[s^i_t - s^i_{t-y}]}{\sum_{i\in g_{t,t-y}}\left[\frac{v^i q^i_t}{\sum_{i\in g_{t,t-y}} v^i q^i_t} \times \frac{p^i_t}{v^i}\right]}$, and, $s^i_t = \frac{v^i q^i_t}{\sum_{i\in g_{t,t-y}} v^i q^i_t}$
  - $\pi^{UC}_t = \left(P^{UC}_t(g) - P^{UC}_{t-y}(g)\right)/P^{UC}_{t-y}(g),$

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POINT-OF-SALES DATA

Point-of-Sales Data

- We use Japanese store-level weekly scanner data, known as the **SRI**, collected by INTAGE Inc.
- Sales records in the dataset cover sales of **processed foods**, **daily necessities**, and **cosmetics** that have commodity codes, **Japanese Article Number**
- The sample period is between **January 2006** and **February 2016**
- The dataset cover various types of stores,
  - general merchandise stores
  - supermarkets
  - convenience stores
  - drug stores
  - specialized stores
- Products are classified into more than **1000 categories**
- The data includes over **22,000 makers**
- The dataset contains detailed **information of the volume of contents**, such as weight (milliliters or grams), number of items, and number of meals, number of times each laundry detergent can be used for washing

Summary of Point-of-Sales Data

- The summary of statistics by store type

Store Type	Statistics	# of stores	# of catgories	# of makers	# of products	# of obs (thousand)	Sum of sales (mil. yen)
Total	average	3,438	804	14,439	84,958	5,459	11,089
	standard deviation	182	5	395	5,199	540	851
	min	3,114	789	13,590	78,307	4,484	8,643
	max	3,768	813	15,128	95,910	6,671	14,733
General Merchandize Store	average	203	790	10,891	51,606	1,029	2,974
	standard deviation	9	4	286	2,782	121	234
	min	175	778	10,306	47,499	829	2,470
	max	218	803	11,461	57,536	1,262	3,938
Super Market	average	980	792	12,535	61,584	2,348	4,529
	standard deviation	24	5	317	3,060	166	309
	min	929	779	11,870	57,067	1,976	3,359
	max	1,042	804	13,122	68,048	2,802	5,528
Drug Store	average	992	708	7,219	36,491	998	1,442
	standard deviation	26	14	357	3,064	137	144
	min	837	666	6,502	31,263	693	916
	max	1,044	734	7,794	42,709	1,292	2,314
Convenience Store	average	737	388	2,039	8,440	459	551
	standard deviation	31	17	69	289	22	64
	min	648	359	1,899	7,843	393	391
	max	790	435	2,296	9,527	504	760
Other	average	526	753	7,830	43,853	625	1,593
	standard deviation	152	10	485	5,049	119	281
	min	387	734	7,261	37,828	463	1,089
	max	793	776	8,821	54,573	922	2,982

Note:

We drop the data which has the value of elasticities of substitution for demand above those 95 percentiles in both maker and category level

Strategy of Price Index Calculation based on the POS

- The calculation methods of price indexes until category level are shown in the table
- The macro level aggregations are implemented by Sato-Vartia method for all price indexes

Price Index		Brand Level Aggregation method	price	weight	variety effect
Laspeyres		Arithmetic mean	p_t^i/p_{t-y}^i	sales in base period	
Paasche		Harmonic mean	p_t^i/p_{t-y}^i	sales in current period	
Trönqvist		Geometric mean	p_t^i/p_{t-y}^i	average of sales weights at bese and current period	
Sato-Vartia		Geometric mean	p_t^i/p_{t-y}^i	Sato-Vartia weight	
Feenstra		Geometric mean	p_t^i/p_{t-y}^i	Sato-Vartia weight	lambda ratio adjudsted by σ_b
Broda-Weinstein		Geometric mean	p_t^i/p_{t-y}^i	Sato-Vartia weight	lambda ratio adjudsted by σ_b
Unit Value Price	base period	Arithmetic mean	p_t^i/v^i	volume-quantity weight	
	current period	Arithmetic mean	p_{t-y}^i/v^i	volume-quantity weight	

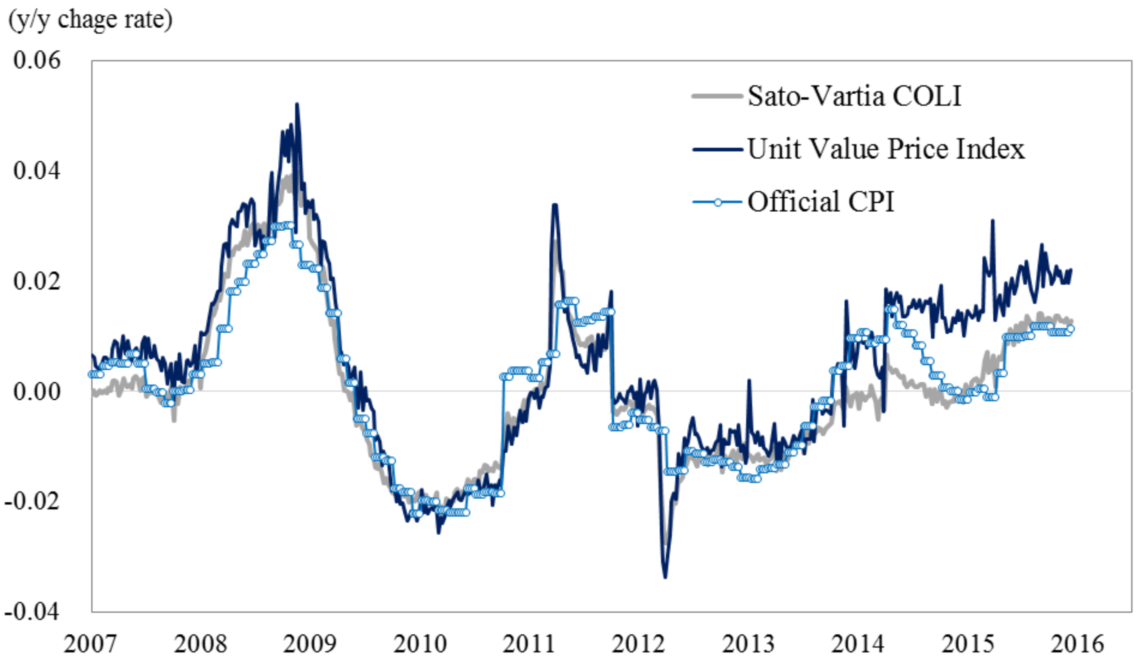
Price Index	Category Level Aggregation method	price	weight	variety effect
Laspeyres	Arithmetic mean	$PI_L\left(p_t, p_{,t-y}, b_{t,t-y}\right)$	sales in base period	
Paasche	Harmonic mean	$PI_P\left(p_t, p_{,t-y}, b_{t,t-y}\right)$	sales in current period	
Trönqvist	Geometric mean	$PI_T\left(p_t, p_{,t-y}, b_{t,t-y}\right)$	average of sales weights at bese and current period	
Sato-Vartia	Geometric mean	$PI_{SV}\left(p_t, p_{,t-y}, b_{t,t-y}\right)$	Sato-Vartia weight	
Feenstra	Geometric mean	$PI_F\left(p_t, p_{,t-y}, b_t, b_{t-y}\right)$	Sato-Vartia weight	
Broda-Weinstein	Geometric mean	$PI_F\left(p_t, p_{,t-y}, b_t, b_{t-y}\right)$	Sato-Vartia weight	lambda ratio adjudsted by σ_g
Unit Value Price	Geometric mean	$P_t^U(b)/P_{t-y}^U(b)$	Sato-Vartia weight	

Effects of New Goods and Product Turnover on Price Indexes

EMPIRICAL RESULTS

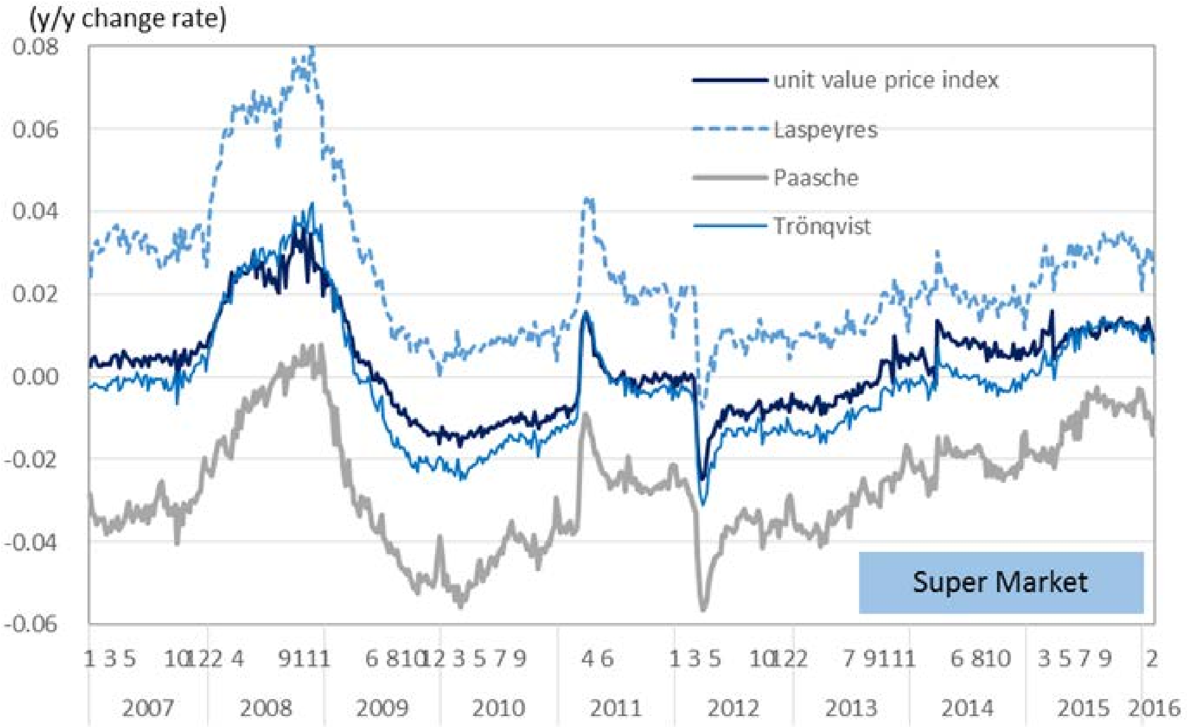
Official CPI v.s. Unit Value Price Index

- We construct the official CPI which consists of the same categories as the unit value price index
- The movements of CPI and Sato-Vartia COLI are very similar
- The CPI and UVPI have similar movements except the periods 2007-2008 and 2014-2015
- Especially, after the consumption tax rate hiking in April 2014, the difference between them has been expanded



Conventional Price Indexes v.s. Unit Value Price Index

- Clearly, all indexes have similar up-and-down movements over time.
- The **Laspeyres** index has a higher inflation rate and the **Paasche** index has a lower inflation rate.
- Those biases come from the bargain sale behavior of the retailers.
- The **UVPI** is slightly higher than the **Trönqvist** index in some time periods.



Estimation of within and across Brand Elasticity of Substitution for Demand

- To calculate Feenstra and Broda-Weinstein COLIs, we need to estimate the elasticities of substitution for demand based on the POS data.
- In this study, we adopt the estimation method of Feenstra (1994)
- We adopt the brands that have estimates for within-brand elasticity of demand with lower values than the 95th percentile
- Also, we adopt the product groups that have estimates of across-brand elasticity of demand with lower values than the 95th percentile

Estimated Elasticities of Substitution for Demand and Supply

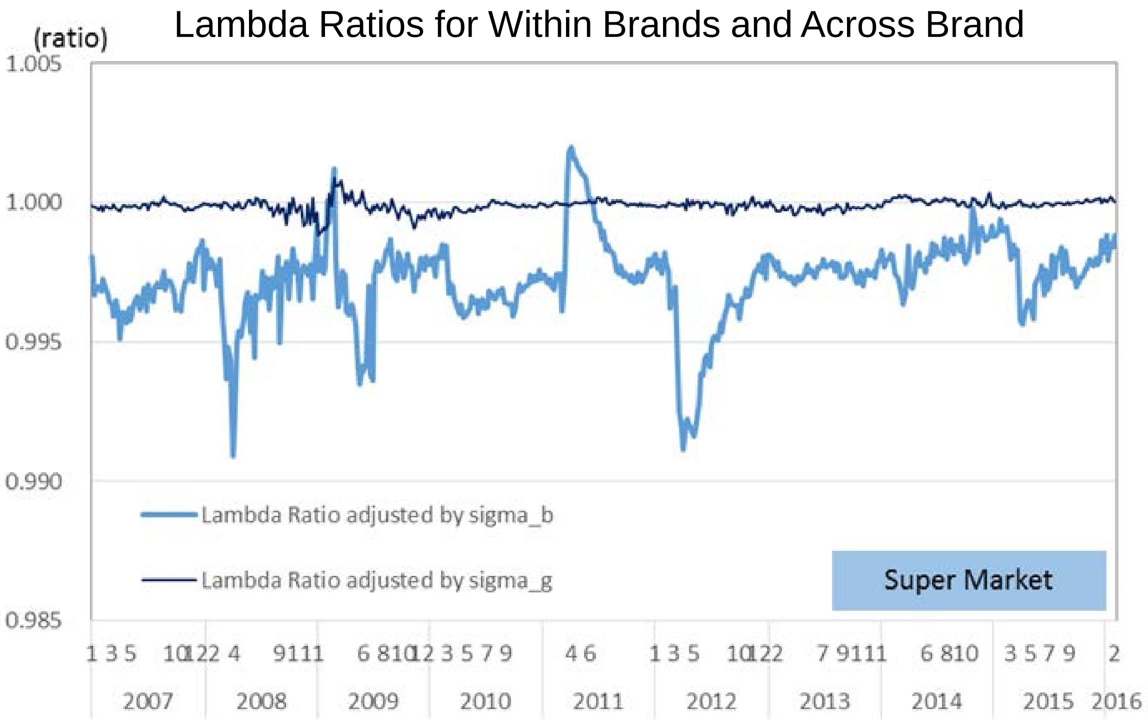
	Within Brand		Across Brand	
	Demand	Supply	Demand	Supply
Percentiles				
0.01	2.842	0.699	1.325	-0.810
0.05	4.336	2.180	2.136	-0.103
0.10	5.344	3.372	2.566	0.470
0.25	7.485	6.238	4.138	2.666
0.50	11.670	11.690	8.769	13.082
0.75	24.596	25.431	32.455	42.874
0.90	74.102	72.531	96.117	104.307
0.95	177.241	167.347	166.129	181.368
0.99	1,749.787	1,928.260	894.507	582.915
Number of Estimates	22,841	22,833	862	862

Cost of Living Indexes with Product Variety and Unit Value Price Index

- The differences from **Sato–Vartia COLI** reveal the effects of product variety change and brand variety change
- **Feenstra COLI and Broda–Weinstein COLI** have lower inflation rates than Sato–Vartia COLI
- **UVPI is generally higher than the Sato–Vartia, Feenstra, and Broda–Weinstein COLIs**
- The remarkable advantage of UVPI is to capture the price change between the new goods and disappeared goods

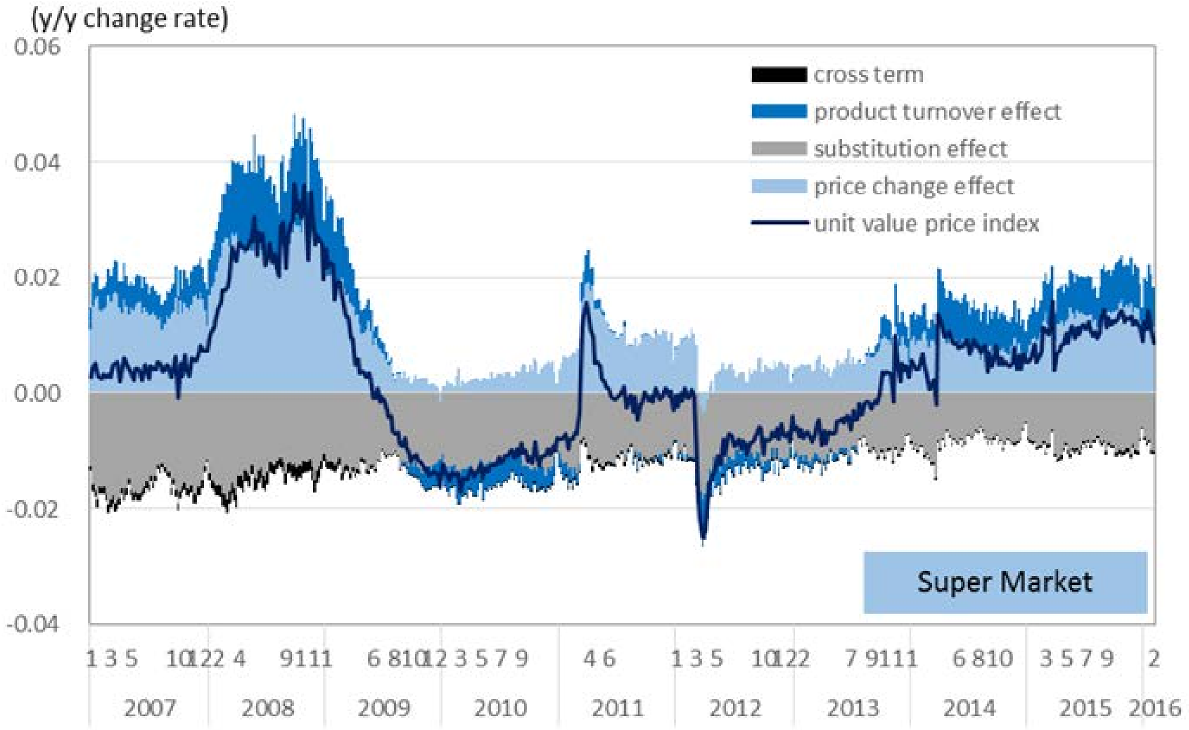
Cost of Living Indexes with Product Variety and Unit Value Price Index

- The figure shows the estimated results of both the within-brand (light blue line) and across-brand (deep blue line) lambda ratios adjusted by substitution elasticities
- we use manufacturer information to identify brands because of the difficulty identifying within-brand variety in a manufacturer's products.
- Thus, the effects of brand variety changes are small

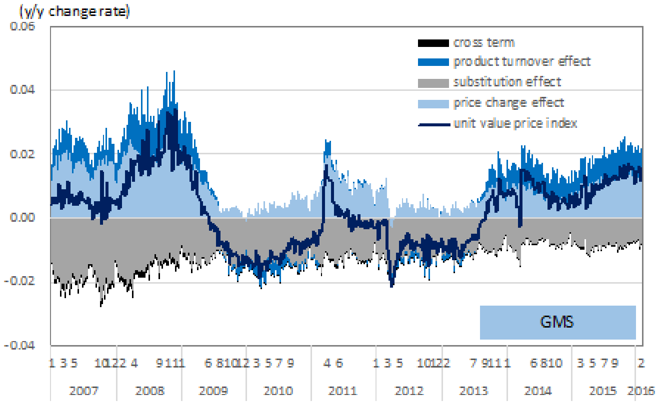


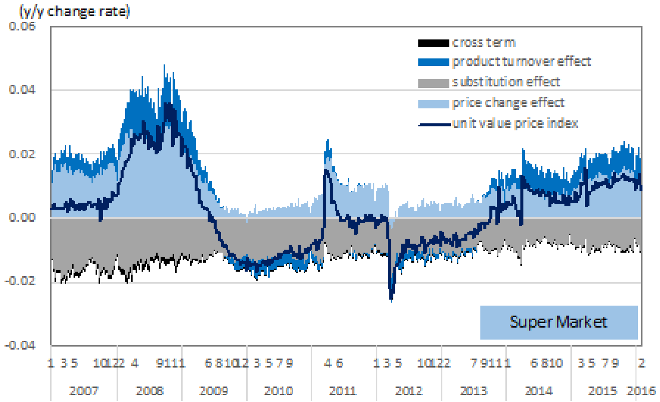
Decomposition of Unit Value Price Index

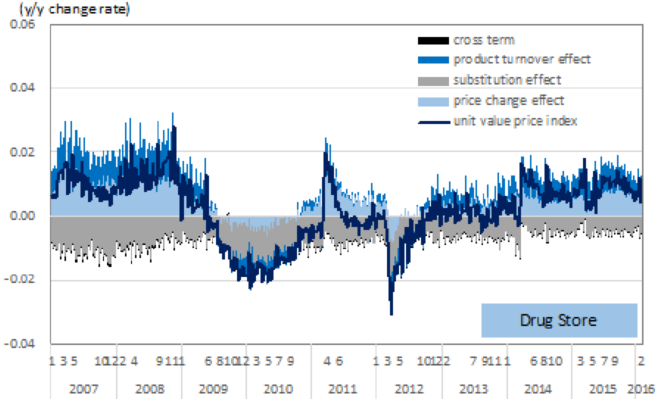
- Positive contributions of the **product turnover effect** during 2007 and 2008 and after 2014
- Many producers raised prices through **product turnover and volume change** in these periods
- The **substitution effects** are generally negative, implying negative correlation between the change of volume shares and prices
- The substitution effects strengthened just before the consumption tax revision in 2014

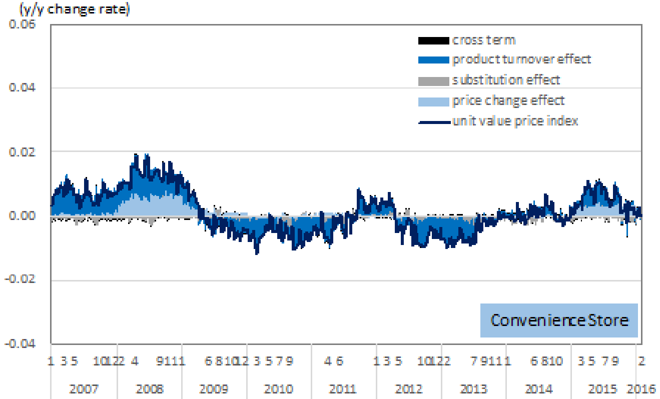


Unit Value Price Index by Store Type

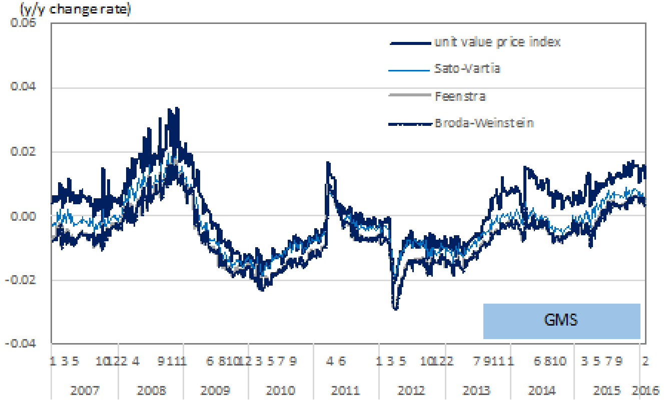


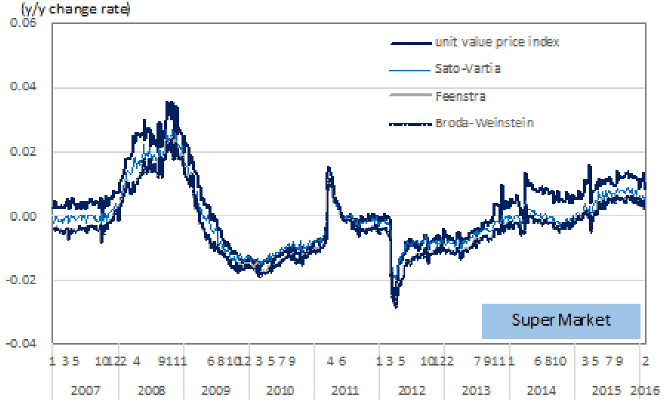


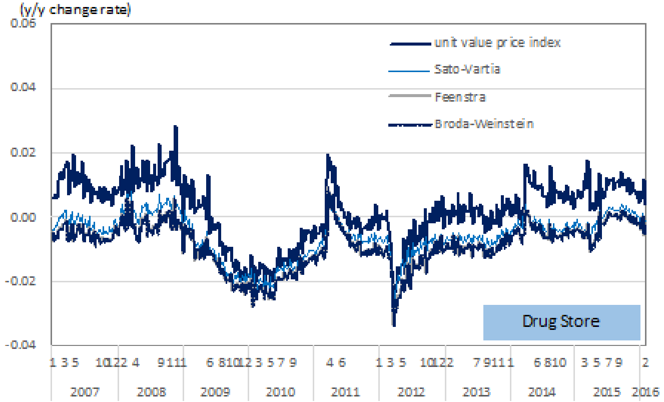


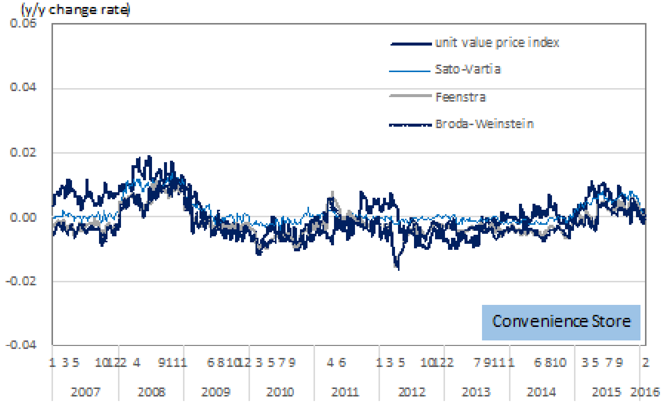


Unit Value Price Index by Store Type









Effects of New Goods and Product Turnover on Price Indexes

CONCLUSION

Conclusion

- This study has investigated **UVPI** and the **COLIs with product variety** based on a **large-scale POS data**
- The UVPI shows a higher rate of inflation than the **official CPI** during the period 2008-2007 and after 2014.
- The movement of official CPI is very similar to the **Sato-Vartia COLI**
- **Feenstra**, and **Broda–Weinstein** COLIs are usually lower than Sato-Vartia COLI, reflected product variety expansion
- The aggregate **UVPI has higher rate of inflation** than other COLIs, such as the Sato–Vartia, Feenstra, and Broda–Weinstein COLIs

Conclusion

- We decomposed changes of UVPI into (1) **price change effects**, (2) **substitution effects**, and (3) **product turnover effects**
- Product turnover effects are generally positive, implying that new products are priced higher than disappearing or continuing goods
- Substitution effects strengthened just before the tax revision, probably reflecting consumer stockpiling behavior
- After the tax rate was hiked, the product turnover effects increased by 1 percentage point, contributing to the increase in UVPI.
- Analyses at the store-type level revealed that the influence of the three effects on UVPI varied greatly across store types.