

## Measuring Price Setting Behaviors Using Scanner Data

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### Abstract

In this paper, we investigate the price setting behavior by using the scanner data. Retailers' price setting behavior is one of the main concerns on macroeconomic issues, as well as an important factor of the inflation trend. Prior researches suggested that the price setting behavior varied from product to product, shop to shop. We use unique data set consists of specific products and shops to eliminate these product/shop variation noises from daily scanner data. We also stand on the prior research's view, that retailers' daily price setting behaviors are based on sticky plans over middle/long terms. According to this idea, we identify the "reference price" as the highest daily basis price in each month and measure the frequency of the "reference price" changes. We also identify the "temporary pricing" based on the reference price and measure the frequency of temporary pricing and discount rates. As a result, after the excluding temporary markdown followed by a return to the previous level, the frequencies of the reference price changes are close to the macroeconomic basis values for Japan estimated by prior researches. The frequency of temporary pricing and discount rates differ from items. Furthermore, we compare the monthly indices of the quantity weighted average price and the reference price. The quantity weighted average price index moves up and down around the reference price index. The reference price index shows some irregular movements.

**Keywords:** Regular Prices, Frequency of Price Changes, Temporary Price Changes, Discounts, Quantity Weighted Average Prices.

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The views expressed in this paper are those of the authors and do not necessarily reflect those of the Ministry of Internal Affairs and Communications (MIC) or the Statistics Bureau.

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## 1. Introduction

Retailers' price setting behavior is one of the main concerns on macroeconomic issues. The degree of price stickiness is an important parameter of the New Keynesian Phillips curve. In standard New Keynesian models, the frequency of price changes influences relations between inflation rates, marginal costs and supply-demand gaps. Prior researches which estimated the new Keynesian Phillips curves revealed the monthly frequency of price changes is about 6% in the United States (Gali and Gertler (1999)) and between 4 to 10 % in Japan (see Table 1). These frequencies were estimated indirectly by macroeconomic approach. On the other hand, growing literatures measured the frequency of price changes directly by using scanner data of retailers' sales information, or microdata of consumer price indices (Kehoe and Midrigan (2015), Anderson et al. (2015), Sudo et al. (2014b), Kurachi et al. (2016)).

Prior researches using scanner data revealed that retailers' price setting behaviors varied from product to product, shop to shop. They also suggested that the importance of how to discriminate between "regular prices/list prices" and temporary pricing, such as bargain-basement prices. Nakamura and Steinsson (2008) pointed out the most of price changes observed on the scanner data were came from the temporary sales, and the frequency of regular price changes was rather close to the macroeconomic-base estimations. Eichenbaum et al. (2011), Kehoe and Midrigan (2015), Guimaraes and Sheedy (2011) developed case studies with new models including sticky regular price changes and high-frequent temporary price settings. Japan's cases were also studied by Sudo et al. (2014b) and Kurachi et al. (2016).

Following these works, many studies are investigating the mechanisms of retailers' price setting behaviors underlying the relations between price changes and temporary pricings. Anderson et al. (2015) pointed out the important view that retailers were assumed to change both their regular prices and temporary sales prices based on the middle/long range "sticky plans". Motivated by this hypothesis, we identify the "reference price" as the monthly highest price, instead of identifying the "regular price" as the monthly most frequent price. We measure the frequency of this "reference

price” change, excluding temporary markdown followed by a return to the previous level. We also identify the “temporary pricing” base on the reference price, measure the frequency of the “temporary pricing” and the discount rate. As a result, our estimation of the frequency of reference price change is close to the macroeconomic estimates of prior researches. The frequency of temporary pricing and discount rate are varied by item.

Retailers’ price setting behaviors is an important factor for measuring the inflation trend. Scanner data enables to analyze comprehensively on daily prices of products and shops. On the other hand, the great diversity of prices possibly delivers noises to aggregated results. We use unique data set consists of specific products and shops to eliminate the product/shop pricing variation noises from daily scanner data. We identify the “reference price” as the highest daily basis price in each month and measure the frequency of the “reference price” changes. We also identify the “temporary pricing” based on the reference price and measure the frequency of temporary pricing and discount rates. As a result, after the excluding temporary markdown followed by a return to the previous level, the frequencies of the reference price changes are close to the macroeconomic basis values for Japan estimated by prior researches. The frequency of temporary pricing and discount rates differ by items. Furthermore, we compare the monthly indices of the quantity weighted average price and the reference price. The quantity weighted average price index moves up and down around the reference price index. The reference price index shows some irregular movements.

The structure of this paper is as follows. Section 2 explains our data. Section 3 explains the methods for measuring price setting behaviors. Section 4 provides results; section 4.1 provides the frequency of “regular price” changes, section 4.2 provides the frequency of temporary pricing and the discount rate, section 4.3 provides reference price indices and quantity weighted average prices. Section 5 concludes.

## **2. Data Description**

We use the National POS Index (NPI) provided by the Distribution Economics Institute of Japan. NPI contains daily sales information of

supermarkets and general merchandise stores thorough Japan. Each record has the number of units sold and its sales (yen, including consumption tax) for a product  $i$  at a shop  $s$  on a date  $td$ . A product  $i$  at a shop  $s$  might have plural different prices in one day because there are not only daily basis discount sales but also limited-time discount sales.

As we mentioned above, prior researches revealed that retailers' price setting behaviors were varied from product to product, shop to shop. Scanner data has the great diversity of prices, so it possibly delivers noises to aggregated results. So we pick up shops, items and products as follows (see Table 2): First, we select 4 items of "ketchup", "yogurt", "potato chips" from the category "processed food" and "laundry detergent" from the category "domestic non-durable goods". Then we select a product for each item which were sold every month from January 2012 through December 2015, and shops which sold these products every month through the same 48 months. ( Note that there are several days without actual sales even in these months. ) As a result, each item has 148 to 189 shops' data. It becomes 13,000 to 26,000 numbers of prices each (see Table 3, Figure 1).

### **3. Measuring Price Settings**

In this section, we describe the methods for measuring price setting behaviors on our data set. 3.1 explains the method to detect monthly "reference prices" from daily prices and to measure the frequency of reference price changes. 3.2 explains how to identify temporary sales pricing and measure the frequency of temporary sales pricing and discount rates. 3.3 explains the method for calculating monthly quantity weighted prices. 3.4 explains the method for calculating indices of quantity weighted prices and reference prices.

#### **3.1 Reference Price**

Each record in the data set has the number of units sold and its sales (yen) for a product  $i$  at a shop  $s$  on a date  $td$ . The price for a product  $i$  at a shop

$s$  on a date  $td$  ( $P_{s,i,td}$ ) is described by the following formula with the sales ( $S_{td}^{s,i}$ ) and the number of units sold ( $Q_{td}^{s,i}$ ):

$$P_{s,i,td} = \frac{S_{td}^{s,i}}{Q_{td}^{s,i}}$$

Many prior researches use the most frequent price over a certain period as the “regular/list prices” (for instance, Eichenbaum et al. (2011), Kahoe and Midrigan (2015), Sudo et al. (2014a), Kurachi et al. (2016)). But it means that “temporary prices” could be higher than “regular/list prices”. On the other hand, Anderson et al. (2015) pointed out the important view that retailers were assumed to change both their regular prices and temporary sales prices based on the middle/long range “sticky plans”. Following this hypothesis, we use the “reference prices” as the monthly highest price instead of the “regular/list prices” as the monthly the most frequent price. The reference price for a product  $i$  at a shop  $s$  during a month  $tm$  ( $P_{s,i,tm}^{(R)}$ ) is defined by the following formula:

$$\text{Reference Price: } P_{s,i,tm}^{(R)} = \max_{td \in tm} (P_{s,i,td})$$

We measure the frequency of this reference price changes as follows: we define that the reference price change is occur in a target month when the reference price of the target month is higher/lower than that of the previous month. We exclude the following cases that (1) the price difference smaller than 2 yen to eliminate the impact of limited-time discount sales on daily basis prices, (2) the reference price change occurred in April 2014 to eliminate the impact of Japan’s consumer tax rate increase, (3) the upward reference price change occurred just after the downward change to eliminate a temporary markdown followed by a return to the previous level. As for (3), we apply ideas of filters to identify the temporary price changes (see 3.2).

### 3.2 Temporary Pricing

A number of mechanical filters are developed to identify temporary price changes in daily basis price data. Among these filters, Eichenbaum et al. (2011), Kehoe and Midrigan (2015), Sudo et al. (2014a), Kurachi et al. (2016) employed “Running Mode filter”, which identified the temporary pricing when a price differed from the most frequent price over certain period. Nakamura and Steinsson (2008) developed “V-Shaped filter”, which identified the temporary pricing as a V-shaped price movement (price down followed by a return to the previous level).

We improve these approaches by the hypothesis pointed out by Anderson et al. (2015). We identify the temporary pricing as the discount rate setting behavior against to the reference price. Estimation formula is the following:

$$\text{Temporary Pricing: } \frac{P_{s,i,td}}{P_{s,i,tm}^{(R)}} < 1$$

We define the temporary pricing occurring when the discount rate ( $P_{s,i,td}/P_{s,i,tm}^{(R)}$ ) is smaller than 1 (we exclude the cases that the price difference smaller than 2 yen as well). Considering the reference price change may occur in middle of a month, we identify the reference price for daily basis temporary pricing estimation by reference price change patterns (in detail, see Appendix).

We calculate the frequency of temporary pricing as dividing the number of temporary pricing by actual sales. The yearly average of the discount rate for a product  $i$  is calculated as follows: (1) we calculate the yearly average of the discount rate for a product  $i$  at a shop  $s$  by arithmetic means. (2) The yearly average of the discount rate for product  $i$  is calculated by arithmetic means of (1). We aim to see discount rates at the retailers’ price settings, rather than wanting to see discount levels on the actual sales.

### 3.3 Quantity Weighted Average Price

The quantity weighted average price for a product  $i$  at a shop  $s$  on a day  $td$  in a month  $tm$  ( $P_{s,i,tm}^{(Q)}$ ) is defined by the following formula:

$$\text{Quantity Weighted Average Price: } P_{s,i,tm}^{(Q)} = \sum_{td \in tm} \left[ \left( \frac{Q_{td}^{s,i}}{\sum_{td \in tm} Q_{td}^{s,i}} \right) P_{s,i,td} \right]$$

### 3.4 Monthly Basis Indices

The monthly basis prices for a product  $i$  in a month  $tm$  are defined as follows:

$$\text{Monthly basis quantity weighted average price: } P_{i,tm}^{(Q)} = \frac{1}{n} \sum_{s=1}^n P_{s,i,tm}^{(Q)}$$

$$\text{Monthly basis reference price: } P_{i,tm}^{(R)} = \frac{1}{n} \sum_{s=1}^n P_{s,i,tm}^{(R)}$$

The monthly basis indices from January 2012 through December 2015 (i.e. 48 months) are calculated as follows:

$$\text{The monthly index of quantity weighted average price: } I_{i,tm}^{(Q)} = \frac{P_{i,tm}^{(Q)}}{\sum_{m=1}^M P_{i,tm}^{(Q)}} \times 100$$

$$\text{The monthly index of reference price: } I_{i,tm}^{(R)} = \frac{P_{i,tm}^{(R)}}{\sum_{m=1}^M P_{i,tm}^{(R)}} \times 100$$

$$(M = 48, \text{ January 2012 to December 2015} = 100)$$

## 4. Results

### 4.1 Frequency of Reference Price Change

The frequencies of the reference price (see Figure 2) changes are 5.9 to 6.6 % per month (see Table 4). These are close to the macroeconomic basis estimation for Japan (see Table 1).

### 4.2 Frequency of Temporary Pricing and Discount Rate

The frequencies of the temporary pricings (see Figure 3) are differ from each item (see Table 5, Table 6). As for the frequency of price changes, “yogurt” shows higher level as 28.5 % per year, the other 3 items show about 15 % per year. As for the yearly average discount rates, “processed food” items are lower than -10 % meanwhile “laundry detergent” is higher than -10 %. It may suggest the differences of storage lives or purchase frequencies among items, but further researches are expected.

### **4.3 Reference Price vs Quantity Weighted Average Price**

The monthly indices show that the quantity weighted average price is fluctuated around the reference price (see Figure 4).

It suggests that the reference price plays a role as a criteria for the temporary pricing, which are occurred seasonally or irregularly over months. Up and down movement possibly reflects temporary discount sales followed by a return to the previous price level. However, the volatility of the quantity weighted average price might be smaller by using the noise-controlled data set including broader range of shops and products (law of large numbers). Or, temporary discount sales might still influence the quantity weighted average price.

The reference price index also shows the irregular movements. It suggests that the reference price has the temporary markdown followed by a return to the previous level. Retailers’ pricing plans possibly has the middle/long range (longer than a month) stickiness.

## **5. Conclusion**

### **5.1 Summary**

We investigate the price setting behavior by using the scanner data. We use unique data set consists of specific products and shops to eliminate the product/shop pricing variation noises from daily scanner data. We identify the “reference price” as the highest daily basis price in each month and measure



the frequency of the “reference price” changes. We also identify the “temporary pricing” based on the reference price and measure the frequency of temporary pricing and discount rates. As a result, after the excluding temporary markdown followed by a return to the previous level, the frequencies of the reference price changes are close to the macroeconomic basis values for Japan estimated by prior researches. The frequency of temporary pricing and discount rates differ from items. Furthermore, we compare the monthly indices of the quantity weighted average price and the reference price. The quantity weighted average price index moves up and down around the reference price index. The reference price index shows some irregular movements.

## **5.2 Issues in the Future**

Our approach to identify price setting behaviors seems to work well on our limited scanner data set. It remains to investigate to apply our approach on the broader range of scanner data set. Our results complements the suggestion that the retailers’ daily price setting behaviors are based on middle/long range sticky plans. Further researches are expected to elucidate the mechanisms deciding the frequency of temporary pricing and discount rates. As for the mechanisms, we just suggests the impact of storage lives and purchase frequencies in this paper.

It is important to understand retailers’ price setting behaviors, especially the relation between price setting and temporary pricing, to measure the inflation rate more precisely. Many research concluded that the temporary pricing has rather small impact on macro-base inflation (Kehoe and Midrigan (2015), Anderson et al. (2015)). On the contrary, prior researches, such as Sudo et al. (2014b) and Kurachi et al. (2016), pointed out the macro-base price stickiness is possibly change by the frequency of temporary pricing. In any case, the importance of scanner data are increasing to investigate the retailers’ price setting behaviors and measure the inflation rate.

## Appendix      Identifying the Patterns of the Reference Price Changes and the Temporary Pricing

Patterns of the Reference Price Changes				Temporary Pricing
	<i>tm-1</i>	<i>tm</i>	<i>tm+1</i>	
a.	—	—	—	<div style="border: 1px solid black; padding: 10px; width: fit-content; margin: auto;"> <math display="block">\frac{P_{s,i,t,d}}{P_{s,i,t,m}^{(R)}}</math> </div>
b.	/	—	—	
c.	—	/	/	
d.	/	/	/	
e.	/	—	—	<div style="border: 1px solid black; padding: 5px; display: inline-block;"> <math>\frac{P_{s,i,t,d}}{P_{s,i,t,m-1}^{(R)}} \leq 1</math> </div> <span style="margin-left: 10px;">Yes → OK</span>
f.	/	/	/	<div style="border: 1px solid black; padding: 5px; display: inline-block;"> <math>\frac{P_{s,i,t,d}}{P_{s,i,t,m}^{(R)}}</math> </div>
g.	—	/	/	<div style="border: 1px solid black; padding: 5px; display: inline-block;"> <math>\frac{P_{s,i,t,d}}{P_{s,i,t,m+1}^{(R)}} \leq 1</math> </div> <span style="margin-left: 10px;">Yes → OK</span>
h.	/	/	/	<div style="border: 1px solid black; padding: 5px; display: inline-block;"> <math>\frac{P_{s,i,t,d}}{P_{s,i,t,m}^{(R)}}</math> </div>
i.	/	/	/	<div style="display: flex; justify-content: space-around; align-items: center;"> <div style="border: 1px solid black; padding: 5px; display: inline-block;"> <math>\frac{P_{s,i,t,d}}{P_{s,i,t,m-1}^{(R)}}</math> </div> <span>or</span> <div style="border: 1px solid black; padding: 5px; display: inline-block;"> <math>\frac{P_{s,i,t,d}}{P_{s,i,t,m}^{(R)}}</math> </div> <span>or</span> <div style="border: 1px solid black; padding: 5px; display: inline-block;"> <math>\frac{P_{s,i,t,d}}{P_{s,i,t,m+1}^{(R)}}</math> </div> </div>

- 1) Identify the patterns of monthly reference price changes.
- 2) Case a. to d.: Identify the temporary pricing using by the reference price of the target month.
- 3) Case e. and f.: Start calculation from the 1st day of the target month.  
Calculate the daily discount rate by using the reference price of the previous month.  
After that the discount rate >1, calculate the daily discount rate by using the reference price of the target month.
- 4) Case g. and h.: Start calculation from the last day of the target month.  
Calculate the daily discount rate by using the reference price of the next month.  
After that the discount rate >1, calculate the daily discount rate by using the reference price of the target month.
- 5) Case i.: Conduct both 3) and 4).

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## Tables and Figures

**Table 1 Macro-base Frequency of Price Changes for Japan (Prior Research)**

Prior Researches	Frequency of Price Changes
Ichiue, Kurozumi and Sunakawa (2013)	9 % per Month
Iiboshi, et al. (2015)	5 to 8 % per Month
Kaihatsu and Kurozumi (2014)	4 % per Month
Kurachi, Hiraki and Nishioka (2016)	6 to 10 % per Month

**Table 2 Items and Products in Our Data Set**

Category 1	Category 2	Items	Products
Processed food	Seasonings	Ketchup	Kagome Tomato Ketchup, 500g
	Dairy products	Yogurt	Meiji Bulgaria Yogurt LB81, 450g
	Cakes and Candies	Potato chips	Calbee Lightly Salted Potato Chips, 60g
Domestic non-durable goods	Detergent	Laundry detergent	Kao Biozet Attack Laundry Powder, 1kg

**Table 3 Number of Shops and Prices in Our Data Set**

Items	Number of Shops	Number of Prices				
		2012	2013	2014	2015	Total
Ketchup	148	45,551	45,826	44,337	44,665	180,379
Yogurt	189	66,517	66,575	66,595	66,900	266,587
Potato chips	173	54,902	54,760	54,522	53,948	218,132
Laundry detergent	155	37,303	35,900	32,002	29,711	134,916

**Table 4 Frequency of Reference Price Changes**

Items					(% per Month)
	2012	2013	2014	2015	Total
Ketchup	4.3	3.3	6.4	10.8	6.2
Yogurt	5.6	4.8	6.9	9.2	6.6
Potato chips	4.3	5.4	6.6	7.2	5.9
Laundry detergent	7.6	6.1	6.3	5.6	6.4

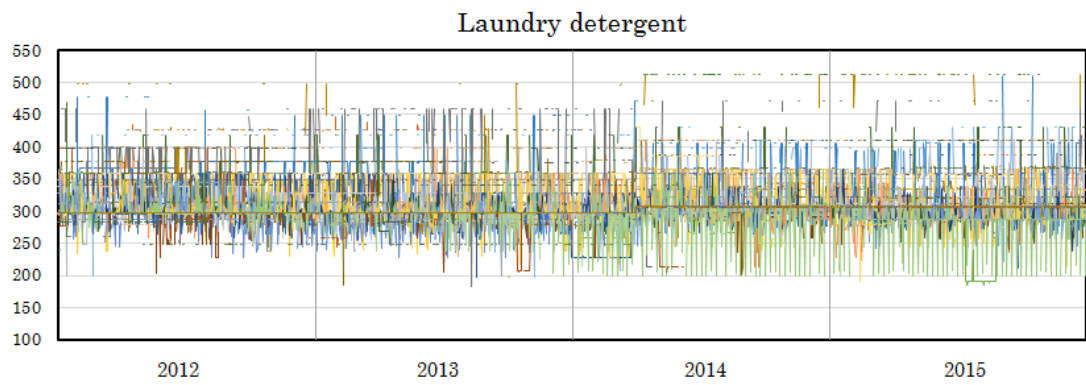
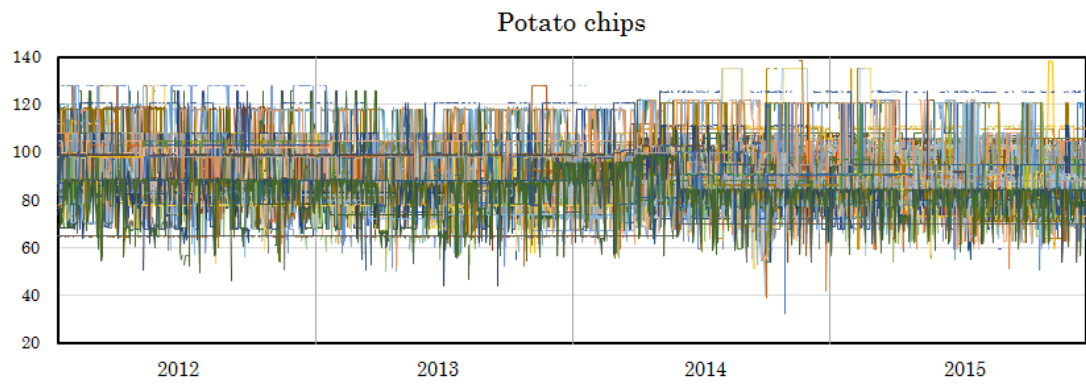
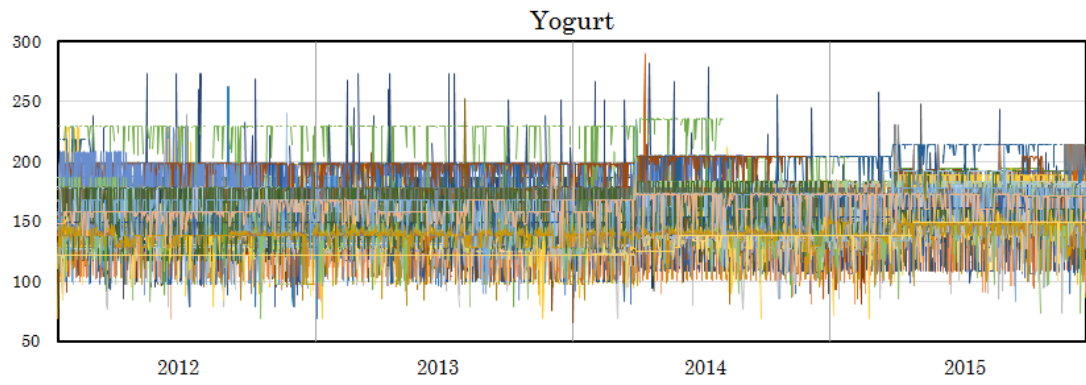
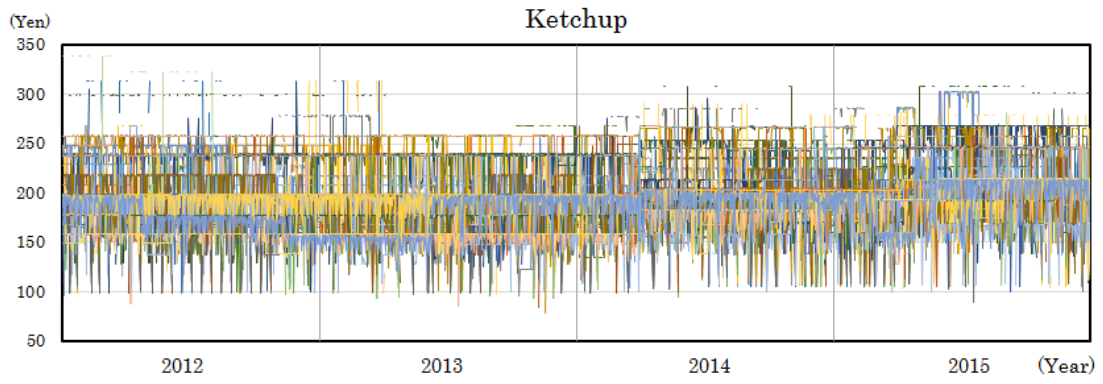
**Table 5 Frequency of Temporary Pricing**

Items					(% per Day)
	2012	2013	2014	2015	Total
Ketchup	15.8	13.3	14.9	15.4	14.8
Yogurt	27.5	28.5	30.0	27.8	28.5
Potato chips	17.5	17.8	15.4	15.7	16.6
Laundry detergent	13.7	14.7	16.3	15.2	15.1

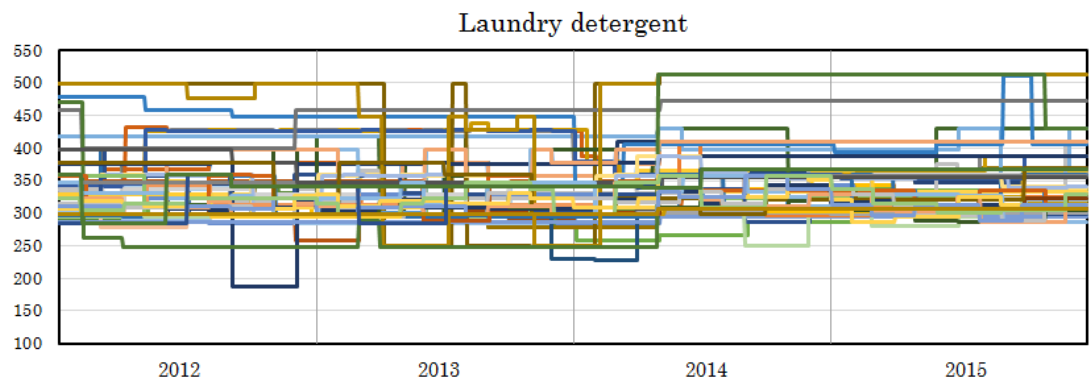
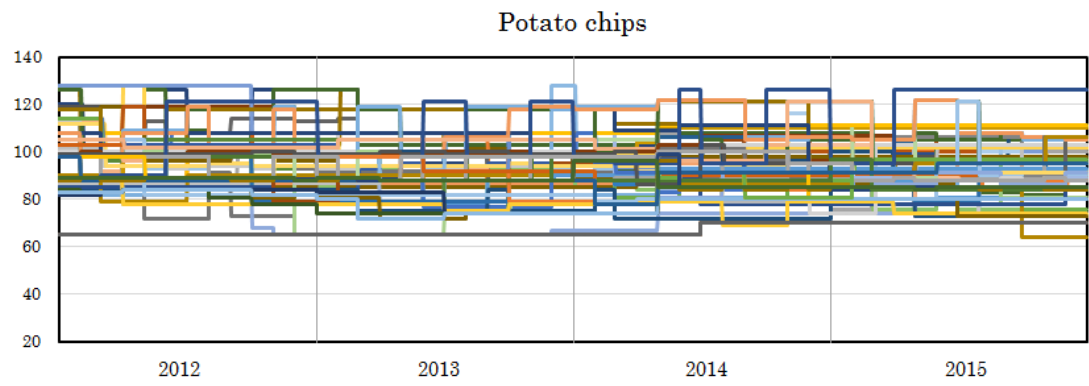
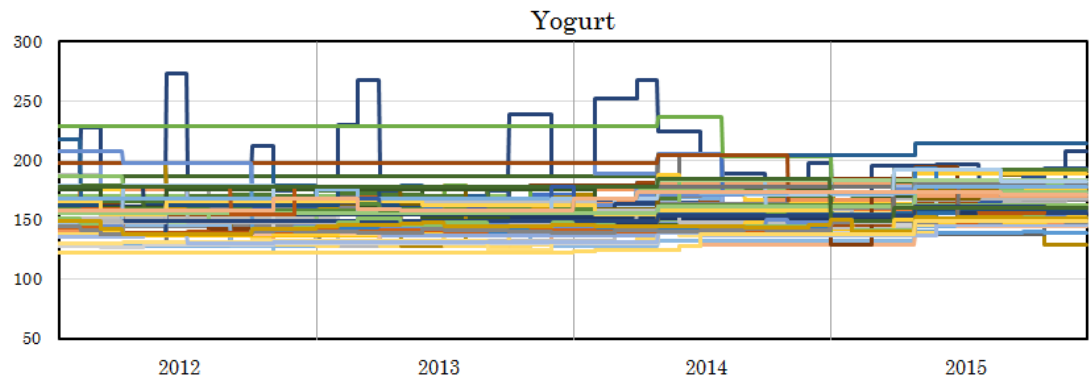
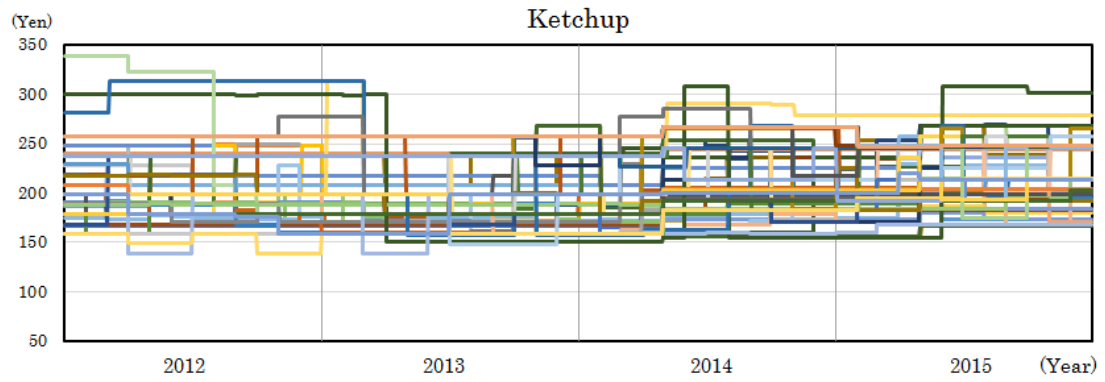
**Table 6 Yearly Average of the Discount Rate of Temporary Pricing**

Items					(%)
	2012	2013	2014	2015	Total
Ketchup	-15.0	-15.6	-15.2	-16.0	-15.3
Yogurt	-13.4	-12.6	-11.0	-10.7	-11.9
Potato chips	-13.2	-13.9	-13.8	-12.9	-13.2
Laundry detergent	-9.3	-8.0	-7.0	-7.4	-8.3

**Figure 1 Raw Data: Daily Prices**

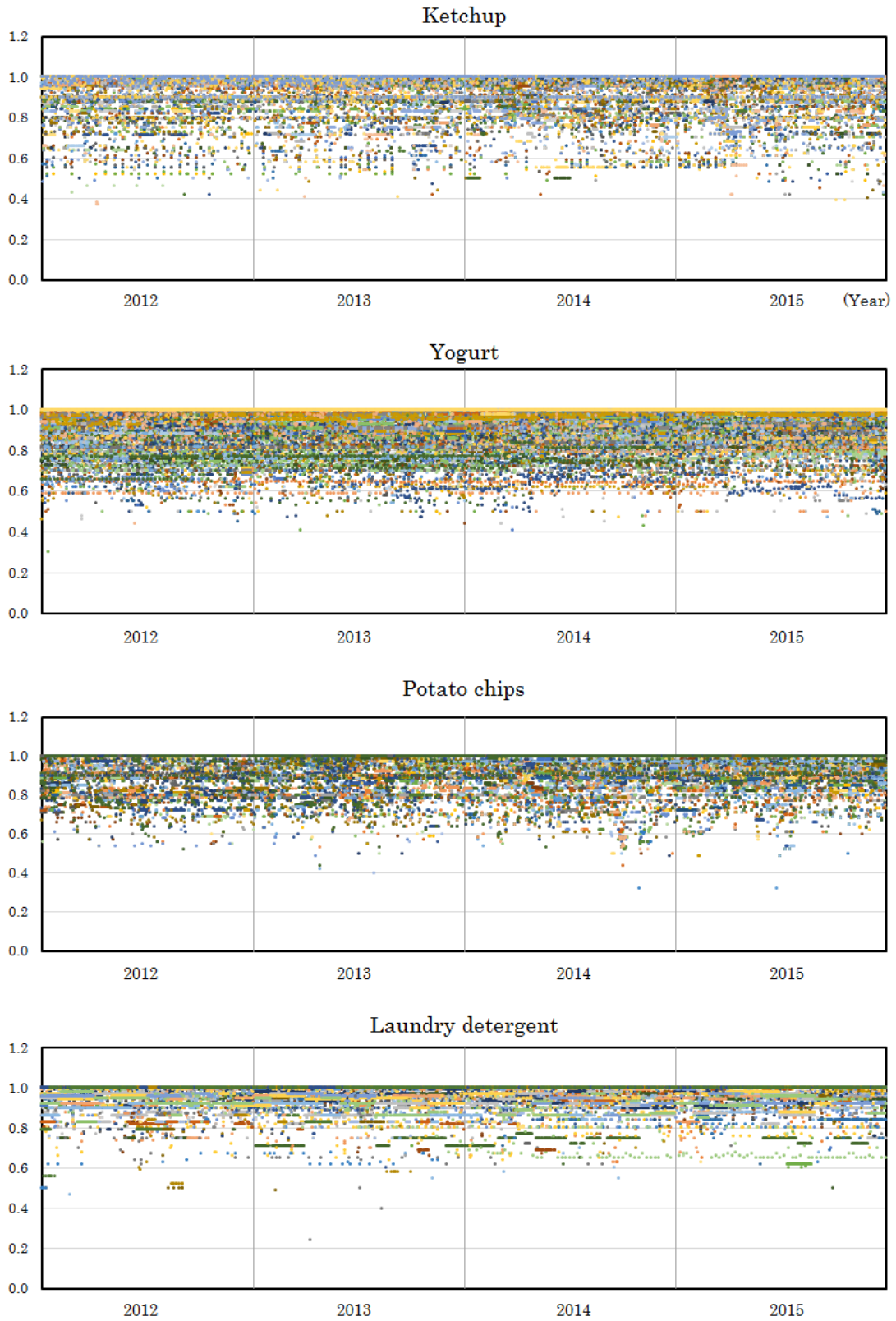


**Figure 2 Reference Prices**

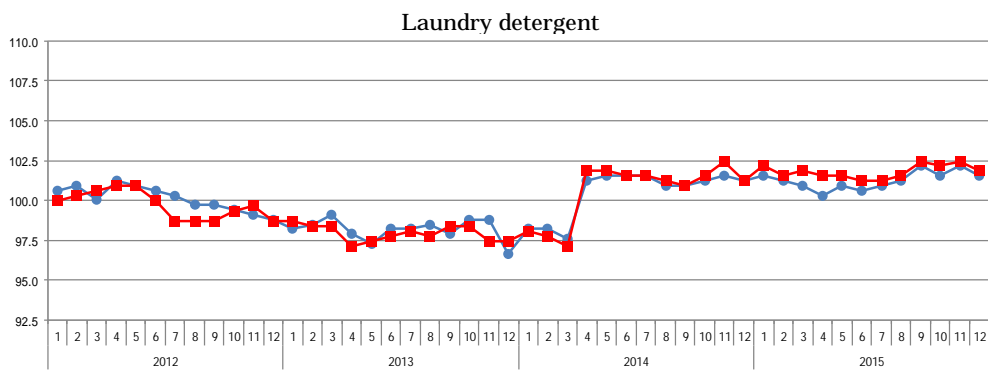
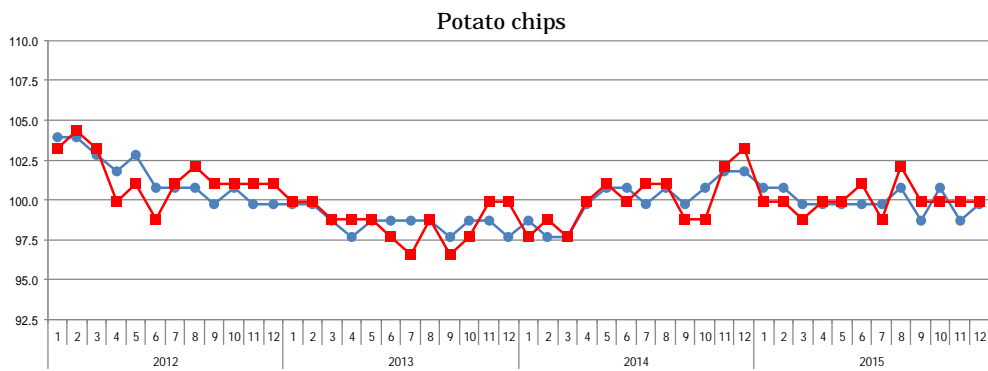
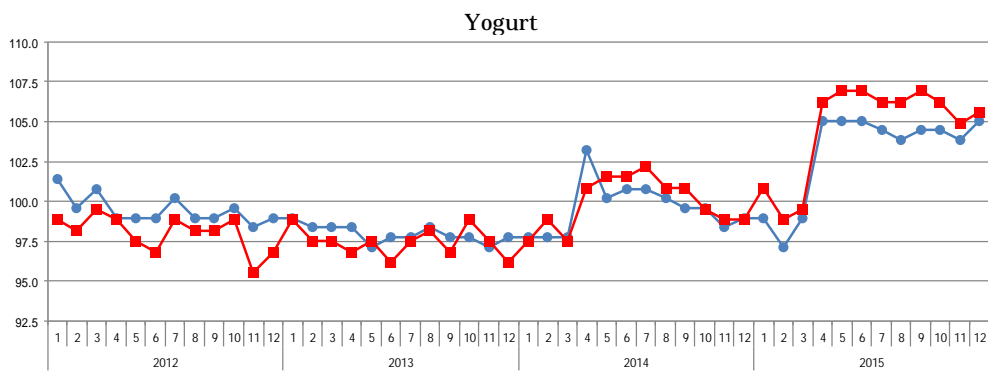
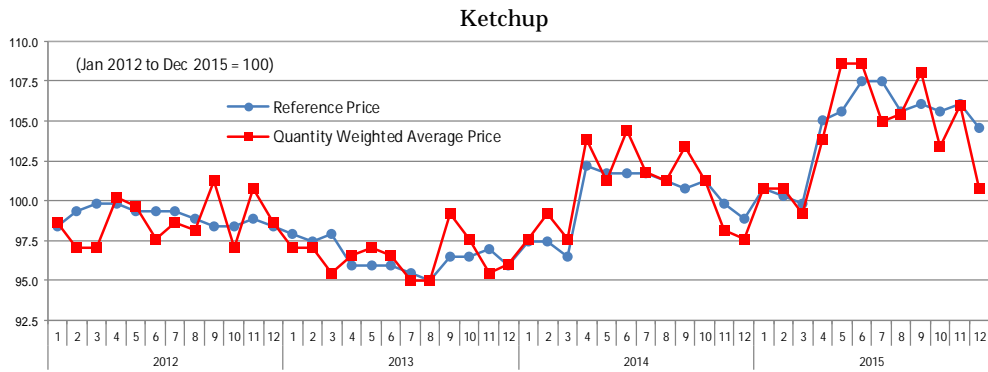




**Figure 3 Price Level of the Daily Prices (Reference Price = 1)**



**Figure 4 Indices of Reference Price and Quantity Weighted Average Price**



(Horizontal Axis: Year and Month)