# What Drove Japan's Deflation: Decomposition Analysis into Regular, Sales, Frequency, and Magnitude Components

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Very very preliminary

**Abstract**

We ask what drove Japan's deflation using daily scanner data. By decomposing the aggregate inflation rate to regular, sales, frequency, and magnitude components, we reveal three facts. First, extensive margin matters for Japan's inflation fluctuations. In particular, the frequency of downward regular price revisions matters in the period of deflation. Second, common shocks play a large role in the fluctuations of regular-price components and the frequency of temporary sales. Third, the frequency of regular price revisions and the frequency of temporary sales are both significantly correlated with macro variables such as hours worked and the lagging index of business cycles. These results may imply that labor market contraction affected deflation through a fall in the frequency of upward regular price changes, a rise in the frequency of downward regular price changes, and a rise in the frequency of sales.

Keywords: Lost decade; deflation; temporary sales; regular prices; scanner data; price stickiness

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# 1 Introduction

Since the asset price bubble went bust in the early 1990s, Japan has gone through very low rates of inflation, and in most of the periods, deflation (see Figure 1). To investigate backgrounds behind the deflation, in this paper, we study micro price dynamics at a retail shop and product level. We employ daily scanner or Point of Sales (POS) data from 1988 to 2013 covering over 6 billion records. Inflation developments are decomposed into two dimensional components: (i) regular and temporary sales and (ii) the frequency and magnitude of price changes. By this decomposition, we study what components drove Japan's deflation.

We reveal three facts. First, extensive margin matters for Japan's inflation fluctuations. In particular, the frequency of downward regular price revisions matters in the period of deflation. Second, while idiosyncratic shocks brings inflation fluctuations, in particular, for the change in magnitude of temporary sales, common shocks also play a large role in the fluctuations of regular-price components and the frequency of temporary sales. Third, the frequency of regular price revisions and the frequency of temporary sales are both significantly correlated with macro variables such as hours worked and the lagging index of business cycles. These results may imply that labor market contraction affected deflation through a fall in the frequency of upward regular price changes, a rise in the frequency of downward regular price changes, and a rise in the frequency of sales.These results may imply that labor market contraction brought deflation through a fall in the frequency of upward regular price changes, a rise in the frequency of downward regular price changes, and a rise in the frequency of sales. Moreover, these results appear to be consistent with a state-dependent pricing model, but needs to incorporate a high degree of idiosyncratic shocks and an endogenous decision of temporary sales in response to macroeconomic developments.

As for the micro price dynamics, Bils and Klenow (2004) are the seminal empirical paper that studies the case in the United States. Klenow and Kryvtsov (2008) and Nakamura and Steinsson (2008) conduct further detailed analysis. A good survey is conducted by Mackowiak and Smets (2009), Klenow and Malin (2011), and Nakamura and Steinsson (2013), although Japan's case is not discussed in details.

Japan's micro price dynamics have been studied by the Bank of Japan (2000), Higo and Saita (2007), Ikeda and Nishioka (2007), Mizuno et al. (2010), Abe and Tonogi

(2010) and Watanabe and Watanabe (2013), Sudo et al. (2014) among others. Our closest and complementary work, except for our previous paper Sudo et al. (2014), is Abe and Tonogi (2010) that employ the same POS data as ours though our data set is longer than theirs by recent seven years. In addition, the two papers differ in terms of sales filter and the fact that we explore the relationship between micro price dynamics and the macro economy.

# 2 POS Data

## 2.1 Data Description

We employ the POS data collected by Nikkei Digital Media from retail shops located in Japan. The data are daily ranging from March 1, 1988 to February 28, 2013, excluding the sample of November and December in 2003. The data consist of records that amounts to 6 billion and each record contains a number of units sold and sales in yen for a product $i$ at a shop $s$ on a date $t$. The cumulative number of products appearing during the sample period is 1.8 million. The data include processed food and domestic articles, and unlike CPI, does not include fresh food, recreational durable goods (TVs and PCs), and services (rent and utility). The coverage of the POS in CPI is 170 out of 588 items, which constitutes 17% of household's expenditure according to Family Income and Expenditure Survey. Each product $i$ is identified by the the Japanese Article Number (JAN) code. In addition, Nikkei Digital Media defines a 3-digit code, from which we classify the types of products such as yogurt, beer, tobacco, and toothbrush. We discard 3-digit code items that are not included in CPI. The sample of retail stores spreads across Japan, but it is biased to relatively large stores. According to Abe and Tonogi (2010), even small stores have 2,000 customers a day. The number of sampled retail shops has increased, reaching 261 in 2012. The number of products has also increased, from 130,000 in the early 1990s to 350,000 in 2012. This trend increase is robustly observed even when the sampled shops were fixed, suggesting the increase in variety of products and the shortening of product cycles during the sample period. See also Imai and Watanabe (2014) and Sudo et al. (2014).

## 2.2 Measuring Prices

From each record of the POS data, we measure the price of a product by its unit price, that is, sales over the number of units sold for a product $i$ at a shop $s$ on a date $t$. As for the date $t$, we pick up a date each month, which is Wednesday in the week that includes 15th of the month. This method is in line with that for official CPI in Japan. Although the POS data are daily, we use monthly data, because an inflation rate obtained by connecting daily price series is known to entail a large downward trend compared with that from monthly price series. This makes it hard to discuss price developments in Japan in association with conventional price indexes like monthly CPI. Recorded sales exclude the contribution of consumption tax that was introduced in April 1989 and raised in April 1997.

Temporary sales are considered to behave differently from regular prices and play a different role in the macro economy. Therefore, it is important to isolate temporary sales from posted prices. The POS data do not tell explicitly which is the sales or not, however, so we need a certain identification method.[1] As a benchmark, we follow Eichenbaum et al. (2011) and define the regular price of a good on a date by the most commonly observed price (mode price) during the 3 months centered on the date.[2] Temporary sales are identified when the regular price differs from its posted price.[3]

Figure 2 depicts a typical pattern of daily price and quantity changes for a certain brand of cup noodle at a certain store at a sampled store. Posted prices are flexible reflecting the presence of temporary sales. Regular prices are revised only 3 times in 4 years. The number of units sold on a day occasionally jumps up by thousand times from that on a previous day.

In this paper, we construct various aggregated variables including the aggregated price index using the POS and examine their time series properties. To do the aggregation, we first obtain a variable of interests, such as a price, for a product $i$ at a shop $s$ on a date

[1]Japan's CPI focuses on the developments in regular prices, not making use of sale prices in constructing its index. Prices with durations of less than seven days are excluded by price surveyors.

[2]To identify regular and sales, we use daily price data.

[3]Eichenbaum et al. (2011) call the price identified as a mode price a "reference price" instead of a regular price since non-mode prices are not necessarily the sale prices: Admittedly, related to this point, 24% of non-mode prices in our data are higher than the mode prices. We maintain the terminology "regular price" throughout the current paper, because we intend to capture general developments in regular price by tracking the movements of mode prices. Our mode-price is, however, conceptually no different from reference price in Eichenbaum et al. (2011). See Sudo et al. (2014) for detailed discussions about the identification of regular and sale prices.

$t$ at the lowest level of JAN codes. Second, we aggregate the variables of interests across shops with sales weights to derive weighted mean.[4] Third, up to the 3-digit code level, we aggregate the weighted means across products with sales weights to derive weighted mean. Last, we aggregate the weighted means across 3-digit codes with sales weights to derive weighted mean or weighted median (quantile). Weights are defined by the sale during the month in the previous year. If a date $t$ is January 18, 2012, for instance, we use the sales of January in 2011 as a weight.

Figure 1 illustrates the yearly inflation rate (%) of the POS price index together with that of CPI. As for the POS, two series are depicted: regular prices that exclude temporary sales and posted prices that include temporary sales. For the comparison purpose, we depict a combined series of processed food and domestic articles for CPI. The figure shows that the POS exhibits similar developments as CPI. After experiencing a positive inflation in the early 1990s, they both witnessed a prolonged deflation until 2008 when commodity prices surged. Two distinct differences exist between POS and CPI. First, POS is systematically lower that CPI. Temporary sales and product entry and exit are considered to cause such a bias. Second, POS exhibits a fast decline in the years from 1992 to 1994 following the bust of the asset-price bubble.

# 3 Decomposing Inflation Rate

## 3.1 Formula for Decomposition

Extending the idea of Klenow and Kryvtsov (2008), we decompose the POS inflation rate of 3-digit code item $i$, $\pi_{i,t} = p_{i,t} - p_{i,t-1}$, to analyze the background of its historical

[4] Nakamura and Steinsson (2008) use sales weights, while Abe and Tonogi (2010) use quantity weights.

developments using the following formula:

$$\begin{aligned}\pi_{i,t} = & \frac{\sum_{j\in i}\omega_{j,t}I\{\Delta p^r_{j,t} > 2.0\}}{\sum_{j\in i}\omega_{j,t}}\cdot\frac{\sum_{j\in i}\omega_{j,t}\Delta p^r_{j,t}I\{\Delta p^r_{j,t} > 2.0\}}{\sum_{j\in i}\omega_{j,t}I\{\Delta p^r_{j,t} > 2.0\}}\\ & + \frac{\sum_{j\in i}\omega_{j,t}I\{\Delta p^r_{j,t} < -2.0\}}{\sum_{j\in i}\omega_{j,t}}\cdot\frac{\sum_{j\in i}\omega_{j,t}\Delta p^r_{j,t}I\{\Delta p^r_{j,t} < -2.0\}}{\sum_{j\in i}\omega_{j,t}I\{\Delta p^r_{j,t} < -2.0\}}\\ & + \frac{\sum_{j\in i}\omega_{j,t}I\{|p_{j,t}-p^r_{j,t}| > 2.0\}}{\sum_{j\in i}\omega_{j,t}}\cdot\frac{\sum_{j\in i}\omega_{j,t}\left(p_{j,t}-p^r_{j,t}\right)I\{|p_{j,t}-p^r_{j,t}| > 2.0\}}{\sum_{j\in i}\omega_{j,t}I\{|p_{j,t}-p^r_{j,t}| > 2.0\}}\\ & - \frac{\sum_{j\in i}\omega_{j,t}I\{|p_{j,t-1}-p^r_{j,t-1}| > 2.0\}}{\sum_{j\in i}\omega_{j,t}}\cdot\frac{\sum_{j\in i}\omega_{j,t}\left(p_{j,t-1}-p^r_{j,t-1}\right)I\{|p_{j,t-1}-p^r_{j,t-1}| > 2.0\}}{\sum_{j\in i}\omega_{j,t}I\{|p_{j,t-1}-p^r_{j,t-1}| > 2.0\}}\\ & + \frac{\sum_{j\in i}\omega_{j,t}\Delta p^r_{j,t}I\{|\Delta p^r_{j,t}| \le 2.0\}}{\sum_{j\in i}\omega_{j,t}}\\ & + \frac{\sum_{j\in i}\omega_{j,t}\left(p_{j,t}-p^r_{j,t}\right)I\{|p_{j,t}-p^r_{j,t}| \le 2.0\} - \sum_{j\in i}\omega_{j,t}\left(p_{j,t-1}-p^r_{j,t-1}\right)I\{|p_{j,t-1}-p^r_{j,t-1}| \le 2.0\}}{\sum_{j\in i}\omega_{j,t}},\end{aligned} \tag{3.1}$$

where $p_{j,t}$ and $p^r_{j,t}$ represent the log posted and regular price of a certain good-shop $j$ at $t$, respectively; $\omega_{j,t}$ represents a weight; and $I\{x\}$is an indicator which returns 1 when $x$ is true. We denote the above equation by

$$\begin{aligned}\pi_{i,t} \equiv\ & fr^{r+}_{i,t}\cdot mg^{r+}_{i,t} + fr^{r-}_{i,t}\cdot mg^{r-}_{i,t}\\ & + fr^{s}_{i,t}\cdot mg^{s}_{i,t} - \tilde{fr}^{s}_{i,t-1}\cdot \tilde{mg}^{s}_{i,t-1} + \varepsilon_{i,t},\end{aligned} \tag{3.2}$$

where $fr^r_{i,t}$ represents the frequency of regular price changes; $mg^r_{i,t}$ represents the magnitude of regular price changes, when it is revised; superscripts + and − represent regular price rises and falls, respectively; and $fr^s_{i,t}$ and $mg^s_{i,t}$ represent the frequency and magnitude of temporary sales, respectively. $\tilde{fr}^s_{i,t-1}$ and $\tilde{mg}^s_{i,t-1}$ resemble the frequency and magnitude of temporary sales at $t-1$, respectively, but they are not exactly so, because weight is that of period $t$. To clarify this, we put tilda ($\widetilde{x}$). We identify a change in the regular price, when the price differs from that in the previous month by more than 2 yen.[5] Similarly, we identify the occurrence of temporary sales, when the price differs from the regular price in the same period by more than 2 yen. Note that not just tem-

[5]The reason behind setting the criteria of 2 yen is that a unit price computed from the sale revenue divided by the number of unit sold may otherwise become non-integers reflecting time sales within a day and/or buy-one-get-one-free sales. In addition, the consumption tax plays a certain role. When a household purchases a basket of several products and Nikkei Digital Media reports the corresponding sales excluding the consumption tax by dividing sales by the tax rate, a unit price of each product is likely to be non-integer. Moreover, in April 2004, consumption tax inclusive pricing was introduced, requiring retail shops to post prices including the consumption tax. That statutory change increased the possibility of decimal prices. See also Eichenbaum et al. (2012) for related discussion.

porary discount but also temporary price premium is also treated as temporary sales in this definition. $\varepsilon_{i,t}$ is the last two lines in equation (3.1), indicating the residual term that embeds minor price changes.

This formula highlights that the inflation rate can be decomposed into two dimensional elements: (1) regular and sales and (2) frequency (extensive margin) and magnitude (intensive margin). Moreover, provided that the fluctuation of each element is small, equation (3.2) can be approximated as

$$\begin{aligned}\pi_{i,t} \simeq & \left(fr_{i,t}^{r+} - \overline{fr_i^{r+}}\right) \cdot \overline{mg_i^{r+}} + \left(fr_{i,t}^{r-} - \overline{fr_i^{r-}}\right) \cdot \overline{mg_i^{r-}} \\ & + \left(mg_{i,t}^{r+} - \overline{mg_i^{r+}}\right) \cdot \overline{fr_i^{r+}} + \left(mg_{i,t}^{r-} - \overline{mg_i^{r-}}\right) \cdot \overline{fr_i^{r-}} \\ & + \left(fr_{i,t}^{s} - \tilde{fr}_{i,t-1}^{s}\right) \cdot \overline{mg_i^{s}} + \cdot \left(mg_{i,t}^{s} - \tilde{mg}_{i,t-1}^{s}\right) \cdot \overline{fr_i^{s}} + \varepsilon_{i,t}. \end{aligned} \tag{3.3}$$

An over-line ($\overline{x}$) indicates time-series mean. This equation suggests that the inflation rate can be decomposed into 7 terms: (1) a deviation of the frequency of upward regular price change from its mean, (2) a deviation of the frequency of downward regular price change from its mean, (3) a deviation of the magnitude of upward regular price change from its mean, (4) a deviation of the magnitude of downward regular price change from its mean, (5) a change in the frequency of temporary sales, (6) a change in the magnitude of temporary sales, and (7) residuals. We then aggregate this across 3-digit code items to derive the aggregate inflation rate and the aggregated contribution of each components to the aggregate inflation rate.

## 3.2 Movements of Regular, Sales, Frequency, and Magnitude Components

Figure 3 displays aggregated time-series developments in the 4 regular price components, that is, $fr_t^{r+}$, $fr_t^{r-}$, $mg_t^{r+}$, and $mg_t^{r-}$. The monthly frequency is around 6 percent for both upward and downward price changes. Its historical developments are not monotonic: the frequency increased steadily from the early 1990 until 2004 and decreased moderately thereafter. The magnitude of regular price changes is roughly 15 to 20% on average. It has been monotonically decreasing over the two decades.

Figure 4 shows aggregated time-series of 4 temporary sales components: $fr_t^s$, $mg_t^s$, $fr_t^s - \tilde{fr}_{t-1}^s$, and $mg_t^s - \tilde{mg}_{t-1}^s$. The figure suggests that temporary sales have become increasingly important in households' expenditure activity during the two decades. The frequency of sales has risen from 20 to more than 25%, indicating that temporary sales take place more than once a four days in the current years. The magnitude of sales $mg_t^s$ has been almost flat, but $mg_t^s - \tilde{mg}_{t-1}^s$ has shown a positive trend.

## 3.3 Decomposition of Inflation Rate

Figures 5 and 6 illustrate the inflation rate decomposition calculated from equation (3.3). Each component is volatile, so to highlight their characteristics, we take the 12-month moving sum for each component. The figures reveal two things. First, as for regular prices, extensive margin tracks well the path of the aggregate inflation rate. In particular, the frequency of downward price changes explains a decline in the inflation rate in the 1990s and early 2000s and a recovery in the late 2000s. The frequency of upward price changes gains high explanatory power when the inflation rate is high around 1991 and 2008. By contrast, intensive margin, that is, the magnitude of price changes, has low explanatory power throughout the periods.

Second, a change in the magnitude of temporary sales is equally or more important for the aggregate inflation rate than the extensive margin of regular prices. A change in the frequency of temporary sales is less important.

To examine the contribution of each component quantitatively, we make variance decomposition for the time-series variance of inflation rate, $\text{var}(\pi_t)$.[6] The first row of Table 1 reconfirms the finding from the figure. The frequency of downward regular price changes and the magnitude of temporary sales matter for the fluctuation of the inflation rate. The second and third rows indicate variance decomposition for differing levels of aggregate inflation rate. When the aggregate inflation rate is higher (lower) than 0.5% (-0.5%), the frequency of upward (downward) regular price changes become increasingly important. This result is consistent with menu cost model, where trend inflation influences the frequency of price changes. The last three rows indicate variance decomposition for the regular-price inflation rate. The aforementioned results hold.

[6] Let $\pi = x + y$. Then we decompose $\text{var}(\pi)$ as $\text{var}(x) + \text{cov}(x, y)$ and $\text{var}(y) + \text{cov}(x, y)$ for $x$ and $y$.

# 4 Analysis of Regular, Sales, Frequency, and Magnitude Components

In the previous section, we decomposed the inflation rate to 7 terms, but this exercise was silent as to as to what influences these terms. In this section, we aim to provide some key properties of the regular, sales, frequency, and magnitude components to help refine economic models and draw policy implications.

## 4.1 Correlation among Regular, Sales, Frequency, and Magnitude Components

First, we examine correlations among regular, sales, frequency, and magnitude components. To do this, for 3-digit code items, we first calculate the time-series mean of interested variables such as the the frequency of upward and downward regular price change depicted in Figures 3 and 4.

A number of existing studies emphasize the importance of the relationship between the magnitude and the frequency of price for better understanding of price dynamics. A negative relationship may imply that different items face a different size of menu cost and a similar size of idiosyncratic shocks.[7] Items that entail large (small) nominal rigidity in changing prices exhibit both low (high) frequency and large (small) magnitude. On the other hand, a positive relationship may imply that different items face a similar size of nominal rigidity and a different size of idiosyncratic shocks like the marginal cost. Items that face larger (smaller) idiosyncratic shocks change their prices more (less) frequently by a larger (smaller) size.

Figure 7 draws a scatter plot, in which horizontal and vertical axes represent the frequency and magnitude of regular price changes, respectively. Each dot denote 3-digit code items. Clearly, they are positively correlated. That is, items with higher frequency of price changes tend to make a greater size of price changes when their prices are revised. This implies the existence of large idiosyncratic shocks.

According to the state-dependent pricing model, the frequency of regular price changes is considered to depend on the inflation rate. The top-right panel in Figure 8 reveals a natural result such that as the level of the inflation rate is lower, the frequency of

[7] Wulfsberg (2009) finds a negative relationship between the frequency and the price change in Norwegian data.

downward price changes increases. Somewhat surprisingly, the top-left panel shows that as the level of the inflation rate is lower, the frequency of upward price changes also increases. Finally, the bottom-left panel draws the relationship between the volatility of inflation rate and the frequency of regular price changes. They are positively correlated, but its direction of causality is ambiguous.

Interestingly, an economic size appears to matter for the pricing, in particular, that of temporary sales. Figure 9 draws a scatter plot, in which a horizontal axis represents the weight of 3-digit code items. Grains, frozen food, and milk are top 3 items in terms of weight. The figure reveal that the weight significantly matters for the price components. In particular, the frequency of sales increases with weight. This may reflect loss leader items. By temporarily lowering popular items, a retailer may aim to attract more customers.

## 4.2 Common and Idiosyncratic Shocks

We next examine whether fluctuations are driven by common or idiosyncratic shocks. For this, we draw the three largest principals among a certain historical time-series of 3-digit code items and calculate the fraction explained by them. Our interested variables are the seven components in equation (3.3) as well as their sum, the POS inflation rate. When a small number of principals explain a large fraction, we can interpret that a common shock plays an important role in fluctuations compared with idiosyncratic shocks.

Table 2 provides results. As for the POS inflation rate, the first (first to third) principal explains 12% (26%). Other fraction is thus caused by idiosyncratic shocks or less important common shocks. It is useful to compare this figure with that of other seven components. Regular price components have higher dependence on common shocks. In particular, as for the frequency of downward regular price changes, the first (first to third) principal explains 20% (41%) of its fluctuations, much higher than that for the POS inflation rate. The frequency of temporary sales also have higher dependence on common shocks with 20% (37%). This suggests that the frequency of temporary sales is influenced by a macroeconomic factor. By contrast, the magnitude of temporary sales have lower dependence on common shocks with 8% (21%). While its contribution to the fluctuations of the inflation rate is large, it is largely driven by idiosyncratic shocks. Because idiosyncratic shocks tend to be washed out over time and across items, its macroeconomic impacts may be smaller.

Figures 10 and 11 illustrate the time-series paths of the first to third principals. Clearly, the principals of the POS inflation rate, the first one particularly, track well the path of the POS inflation rate. Among seven components, those of regular price frequency, both up and down, appear to have high coherence to the inflation rate. They reached a peak in 1991 and 2008, similar to the inflation rate. By contrast, components related to regular price magnitude and sale prices do not exhibit high correlations with the inflation rate.

## 4.3 Correlations with Macro Variables

We found that the fluctuations of some price components are driven largely by common shocks. The next question comes out as to what kind of macro variables are associated with them. To investigate this, we calculate correlations between micro price components and macro variables, although we are not necessarily able to elucidate causality between them or structural sources of correlations. As for micro price components, we look at the POS inflation rate, its seven components depicted in Figures 5 and 6, and its seven times three principals depicted in Figures 10 and 11. As for macro variables, we look at ten time series: the POS inflation rate, the CPI inflation rate (both are month-to-month changes), the unemployment rate, hours worked, the index of industrial production, the leading index, the coincident index, the lagging index, a monthly change in monetary base, the overnight call rate, and the 10-year government bond rate. Leading, Coincident, and Lagging indexes are the components of Composite Indexes complied by Cabinet Office, which serves as useful indicators for Japan's business cycles. Except for the inflation rates and interest rates, all the variables are expressed in logarithm. We choose these macro variables to capture mainly three aspects of the macroeconomy. First, the POS and CPI inflation rates capture developments in aggregate prices. Second, the last three variables, a monthly change in monetary base, the overnight call rate, and the 10-year government bond rate, are proxies for monetary policy. Although the short-term interest rate is the main monetary policy instrument in advanced economies, we also look at the monetary base as well as the long-term government bond rate, taking account of the zero lower bound of nominal interest rate which constrains Japan's monetary policy for more than a decade. The remaining macro variables are in the third category, which captures developments in the real side of the macroeconomy. Samples are from March 1989 to February 2013. For all these variables, we isolate business-cycle components with a period of 1.5 to 8 years using the Baxter-King band pass filter, because short-run monthly fluctuations are extremely volatile and long-run trend may yield spurious correlations. However, using the Baxter-King band pass filter itself yields another spurious correlations, so we calculate the 90% and 95% confidence interval by Monte Carlo simulation and use widened confidence interval.

Tables 3 to 6 provide correlations. In the tables, we report the absolute size of correlations regarding principals, because their sign does not have economic implications. To begin with regular price components, we reconfirm the results in the previous subsection from Table 3. Regular-price frequency components have high and significant correlations with macro inflation rates. In addition, the frequency of upward regular-price revisions is significantly correlated with other macro variables, namely, the unemployment rate, hours worked, the lagging index as well as the call rate and the 10-year rate. A possible explanation for this result is that when the economy is in a boom (recession), the labor market is tightened and retailers raise their prices by raising the frequency of upward regular-price revisions. A rise in the inflation rate is accompanied by a rise in the interest rate through monetary policy. It is also worth pointing out that the frequency of upward regular-price revisions is more highly correlated with macro variables than the macro inflation rates. As Tables 4 to 6 show, the first principal of the frequency of upward regular-price revisions, in particular, exhibits a high correlation with macro variables. By contrast, the frequency of downward regular-price revisions is not significantly correlated with macro variables except for the macro inflation rate and the call rate. Neither is the magnitude of regular-price revisions.

We then turn to sale price components. The components of the frequency of sales is negatively correlated with the lagging index. According to Table 6, its third principal is significantly correlated with the unemployment rate, hours worked, the coincident index, and the lagging index together with the call rate. This suggests that when the economy is in a boom (recession), the frequency of sales goes down (up). In particular, labor market conditions appear to influence retailers' temporary sale decisions. One rationale is that increased unemployment rates or decreased hours worked reduce the disutility of households from bargain hunting activity, and retailers react to this by raising their sale frequency. However, such relations may not be strong, because the first and second principals are not significantly correlated with macro variables. As for the sale magnitude component which is a main driver of macro inflation fluctuations, we find low correlations with macro variables except for the macro inflation rate. Although it is significantly correlated with the leading index in Table 3, the first to third principals do not exhibit significance in Tables 4 to 6, so this may not be a robust result.

# 5 Concluding Remarks

In this paper, we have studied micro price dynamics under Japan's deflation using micro price data and decomposing it into regular, sales, frequency, and magnitude components. We have revealed the following facts. (i) Extensive margin, in particular, the frequency of downward regular price changes matters for Japan's inflation fluctuations. (ii) The level of inflation rate matters for the frequency of regular price changes. (iii) Items with higher frequency of regular price changes tend to have higher magnitude of regular price changes. (iv) While idiosyncratic shocks matter for inflation fluctuations, in particular, for the change in magnitude of temporary sales, the importance of common shocks is large for regular-price components and the frequency of temporary sales. (v) The frequency of regular price changes and the frequency of temporary sales are both significantly correlated with macro variables such as hours worked and the lagging index of business cycles.

What drove Japan's deflation? One direct answer is that changes in the frequency of regular price revisions drove deflation. The frequency of upward (downward) regular price revisions went down (up), contributing to deflation. However, such an answer is just mechanical. Our further analysis suggests the possibility that macroeconomic factors, in particular, those related to the labor market contraction, brought the changes in the frequency of regular price revisions. However, we have not yet shown causality from the macroeconomic factors to retailers' pricing. This is our future task.

To consider causality, we may need a structural model. Our results appear to be consistent with a state-dependent pricing model, but needs to incorporate a high degree of idiosyncratic shocks and an endogenous decision of temporary sales in response to macroeconomic developments. Regarding the role of temporary sale in macroeconomic dynamics, Guimaraes and Sheedy (2011) construct a DSGE model with temporary sales and show that the real effects of monetary policy hardly diminish in the presence of sales, because sales are strategic substitutes. Their argument rests on the presumption that choice of temporary sales is orthogonal to changes in macroeconomic developments.

Kehoe and Midrigan (2010), Eichenbaum et al. (2011), and Anderson et al. (2012) as well as Guimaraes and Sheedy (2011) are its proponents. On the other hand, this paper and Sudo et al. (2011) suggest the opposite possibility, that is, the frequency of temporary sales is influenced by macro business cycles. Klenow and Wills (2007) and Coibon et al. (2012) provide similar evidence. If so, the real effects of monetary policy may be small.

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Table 1: Variance Decomposition of POS Inflation Rate

| | Total (POS inflation rate) | Regular frequency up | Regular frequency down | Regular magnitude up | Regular magnituide down | Sale frequency | Sale magnituide | Residuals |
|---|---|---|---|---|---|---|---|---|
| Posted price | 100 | 10.8 | 24.1 | -0.5 | 1.8 | 26.1 | 36.7 | 1 |
| when $\pi > 0.5$ | 100 | 43 | 3.1 | -0.5 | 1.5 | 28.8 | 40.2 | -16.1 |
| when $\pi < -0.5$ | 100 | 5.1 | 22.2 | 1.5 | 0.3 | 29 | 38.1 | 4.7 |
| Regular price | 100 | 30.7 | 63.4 | 2 | 3.8 | – | – | – |
| when $\pi > 0.5$ | 100 | 69.9 | 18.6 | 5.4 | 6.1 | – | – | – |
| when $\pi < -0.5$ | 100 | 14.4 | 76 | 8.4 | 1.2 | – | – | – |

Table 2: Fraction Explained by Principal Components

| % | Total (POS inflation rate) | Regular frequency up | Regular frequency down | Regular magnitude up | Regular magnituide down | Sale frequency | Sale magnituide | Residuals |
|---|---|---|---|---|---|---|---|---|
| 1st principal | 11.6 | 13.8 | 20.4 | 13.2 | 11 | 19.7 | 8.3 | 14.1 |
| 1st to 2nd principals | 19.4 | 21.9 | 32.3 | 22.1 | 18.7 | 29.4 | 16.4 | 25.4 |
| 1st to 3rd principals | 26 | 29.1 | 40.6 | 29.5 | 24.6 | 37.2 | 21 | 32.4 |

Table 3: Correlation between Price Components (Aggregated across Items) and Macro Variables

| Aggregate | Total (POS inflation rate) | Regular frequency up | Regular frequency down | Regular magnitude up | Regular magnituide down | Sale frequency | Sale magnituide | Residuals |
|---|---|---|---|---|---|---|---|---|
| POS inflation rate | 1** | 0.66** | 0.53** | -0.09 | -0.09 | -0.06 | 0.53** | -0.07 |
| CPI inflation rate | 0.63** | 0.54** | 0.36* | -0.37* | 0.27 | 0.02 | 0.14 | -0.19 |
| Unemploy rate | -0.2 | -0.37* | -0.12 | 0.26 | -0.24 | 0.29 | 0.13 | 0.16 |
| Hours worked | 0.25 | 0.43** | 0.29 | 0.2 | -0.09 | -0.36* | -0.36* | -0.24 |
| Industrial production | 0.28 | 0.36* | 0.27 | -0.12 | 0.13 | -0.02 | -0.29 | -0.17 |
| Leading index | 0.01 | 0.17 | 0.14 | 0.1 | 0.03 | 0.08 | -0.45** | -0.24 |
| Coincident index | 0.28 | 0.40** | 0.32 | 0.07 | 0.12 | -0.20 | -0.36* | -0.22 |
| Lagging index | 0.29 | 0.43** | 0.20 | -0.30 | 0.29 | -0.42** | -0.11 | -0.13 |
| Base money change | 0.14 | -0.12 | 0.17 | 0.29 | -0.25 | -0.08 | 0.40* | -0.12 |
| Call rate | 0.44** | 0.56** | 0.43** | -0.25 | 0.17 | -0.41** | -0.29 | -0.19 |
| 10yr rate | 0.26 | 0.57** | 0.16 | -0.01 | 0.04 | -0.19 | -0.44** | -0.24 |

** and * represent 5% and 10% significance, respectively.

Table 4: Correlation between Price Components (1st Principal) and Macro Variables

| 1st principal | Total (POS inflation rate) | Regular frequency up | Regular frequency down | Regular magnitude up | Regular magnituide down | Sale frequency | Sale magnituide | Residuals |
|---|---|---|---|---|---|---|---|---|
| POS inflation rate | 0.61** | 0.56** | 0.43** | 0.25 | 0.21 | 0.23 | 0.24 | 0.04 |
| CPI inflation rate | 0.43** | 0.52** | 0.32 | 0.29 | 0.07 | 0.08 | 0.16 | 0.04 |
| Unemploy rate | 0 | 0.46** | 0.08 | 0.13 | 0.09 | 0.26 | 0.04 | 0.01 |
| Hours worked | 0.16 | 0.38* | 0.27 | 0.05 | 0.11 | 0.19 | 0.26 | 0.16 |
| Industrial production | 0.17 | 0.34* | 0.24 | 0.21 | 0.11 | 0.13 | 0.02 | 0.15 |
| Leading index | 0.05 | 0.15 | 0.17 | 0.02 | 0.15 | 0.29 | 0.2 | 0.26 |
| Coincident index | 0.16 | 0.37* | 0.31 | 0.17 | 0.02 | 0.03 | 0.13 | 0.21 |
| Lagging index | 0.06 | 0.48** | 0.17 | 0.2 | 0.15 | 0.37* | 0.04 | 0.06 |
| Base money change | 0.15 | 0.05 | 0.17 | 0.24 | 0.11 | 0.17 | 0.01 | 0.1 |
| Call rate | 0.34* | 0.44** | 0.49** | 0.24 | 0.46** | 0.37* | 0.18 | 0.37* |
| 10yr rate | 0.46** | 0.52** | 0.22 | 0.04 | 0.3 | 0.15 | 0.13 | 0.39* |

** and * represent 5% and 10% significance, respectively.

Table 5: Correlation between Price Components (2nd Principal) and Macro Variables

| 2nd principal | Total (POS inflation rate) | Regular frequency up | Regular frequency down | Regular magnitude up | Regular magnituide down | Sale frequency | Sale magnituide | Residuals |
|---|---|---|---|---|---|---|---|---|
| POS inflation rate | 0.1 | 0.12 | 0.15 | 0.33 | 0.21 | 0.29 | 0.02 | 0.1 |
| CPI inflation rate | 0.03 | 0.04 | 0.05 | 0.12 | 0.01 | 0.18 | 0.06 | 0.1 |
| Unemploy rate | 0.03 | 0.29 | 0.48** | 0.02 | 0.03 | 0.12 | 0.09 | 0.21 |
| Hours worked | 0.21 | 0.01 | 0.19 | 0.35* | 0.5** | 0.03 | 0.24 | 0.03 |
| Industrial production | 0.13 | 0 | 0.18 | 0.21 | 0.21 | 0.2 | 0.03 | 0.12 |
| Leading index | 0.26 | 0.07 | 0.13 | 0.22 | 0.33 | 0.31 | 0.04 | 0.02 |
| Coincident index | 0.24 | 0.06 | 0.23 | 0.22 | 0.28 | 0.05 | 0.07 | 0.11 |
| Lagging index | 0.12 | 0.29 | 0.42** | 0.03 | 0.02 | 0.2 | 0.16 | 0.15 |
| Base money change | 0.06 | 0.05 | 0.14 | 0.13 | 0.04 | 0.21 | 0.14 | 0.07 |
| Call rate | 0.47** | 0.05 | 0.04 | 0.01 | 0.21 | 0.4** | 0.17 | 0.11 |
| 10yr rate | 0.42** | 0.07 | 0.1 | 0.03 | 0.23 | 0.18 | 0.01 | 0.1 |

** and * represent 5% and 10% significance, respectively.

Table 6: Correlation between Price Components (3rd Principal) and Macro Variables

| 3rd principal | Total (POS inflation rate) | Regular frequency up | Regular frequency down | Regular magnitude up | Regular magnituide down | Sale frequency | Sale magnituide | Residuals |
|---|---|---|---|---|---|---|---|---|
| POS inflation rate | 0.6** | 0.45** | 0 | 0.08 | 0.03 | 0.15 | 0.4** | 0.06 |
| CPI inflation rate | 0.61** | 0.06 | 0 | 0.08 | 0.02 | 0.11 | 0.39* | 0.07 |
| Unemploy rate | 0.39* | 0.15 | 0.1 | 0.25 | 0.05 | 0.57** | 0.06 | 0.08 |
| Hours worked | 0.18 | 0.17 | 0.36* | 0.29 | 0.15 | 0.47** | 0.27 | 0.26 |
| Industrial production | 0.21 | 0.08 | 0.13 | 0.02 | 0.12 | 0.3 | 0.03 | 0.05 |
| Leading index | 0.09 | 0.11 | 0.25 | 0.23 | 0.33 | 0.18 | 0.29 | 0.13 |
| Coincident index | 0.21 | 0.21 | 0.27 | 0.05 | 0.16 | 0.45** | 0.15 | 0.18 |
| Lagging index | 0.43** | 0.31 | 0.2 | 0.24 | 0.04 | 0.63** | 0.03 | 0.18 |
| Base money change | 0.07 | 0.15 | 0 | 0.12 | 0.13 | 0.24 | 0.01 | 0.06 |
| Call rate | 0.17 | 0.63** | 0.47** | 0.19 | 0.13 | 0.47** | 0.04 | 0.36* |
| 10yr rate | 0.08 | 0.23 | 0.41** | 0.53** | 0.15 | 0.26 | 0.21 | 0.16 |

** and * represent 5% and 10% significance, respectively.

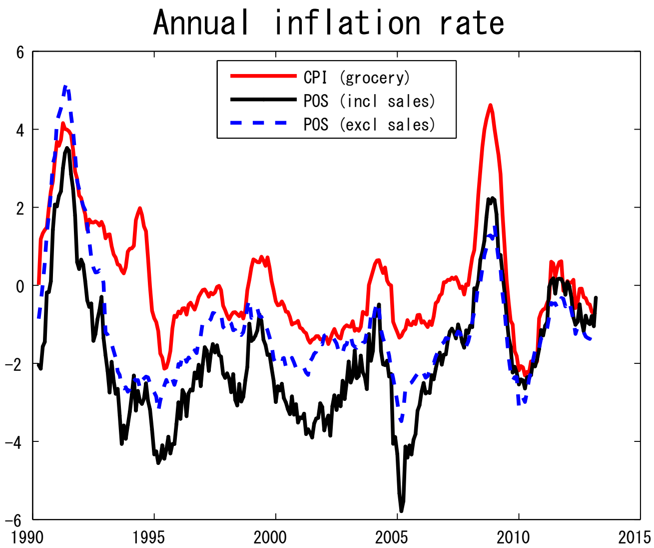



Figure 1: Annual Inflation Rate from CPI and POS
Note: CPI (Grocery) represents the CPI price index that consists of the same item category as the POS data.

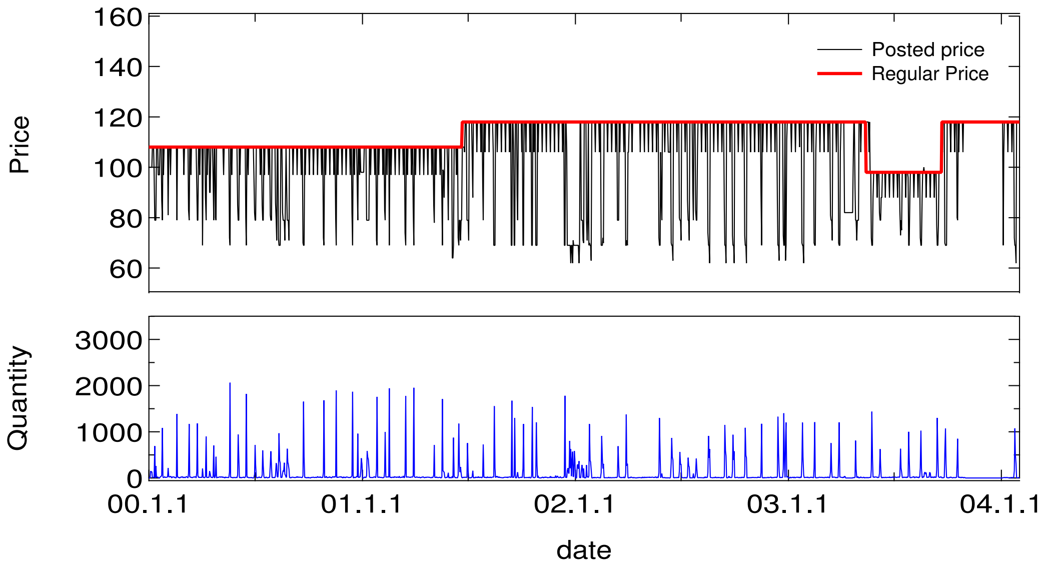



Figure 2: Price Changes of a Cup Noodle at a Store

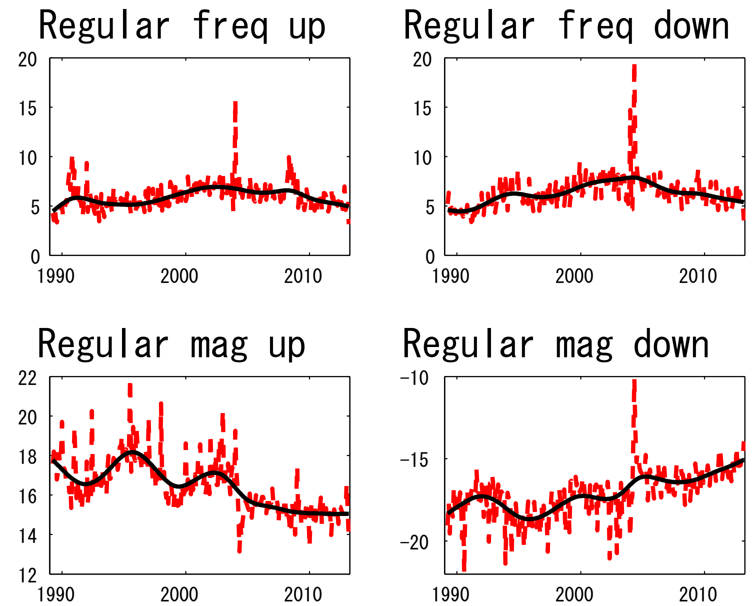
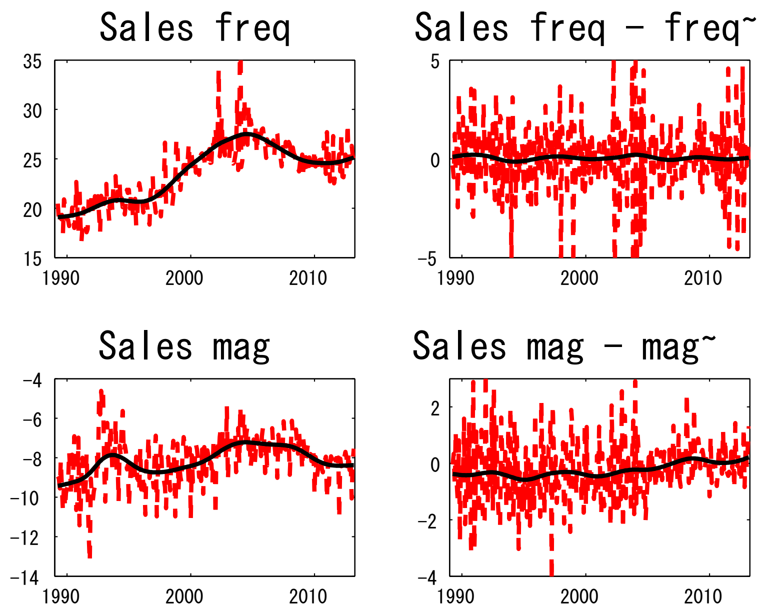



Figure 3: Regular Price Components

Note: A solid line represents the HP filtered series ($\lambda = 14,400$) of the series depicted in a dashed line.

Figure 4: Temporary Sales Components




Note: A solid line represents the HP filtered series ($\lambda = 14,400$) of the series depicted in a dashed line.

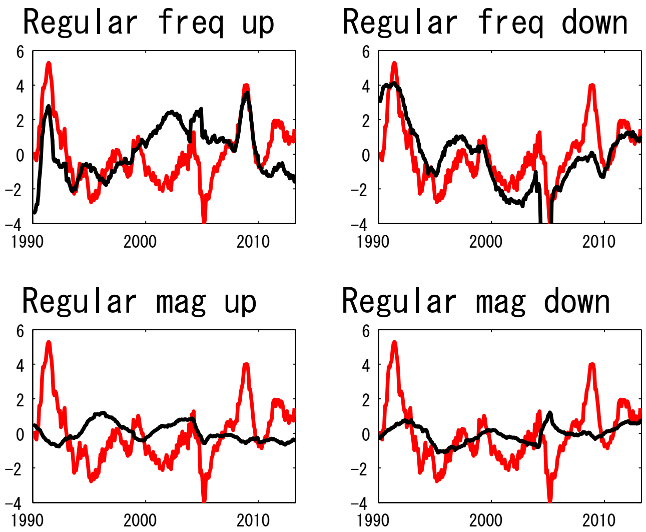



Figure 5: Decomposing Inflation Rate: Regular Price Components
Note: A black solid line with dot represents the contribution of each component to the aggregated inflation rate depicted in a red solid line. All series are expressed in a 12-month backward moving sum.

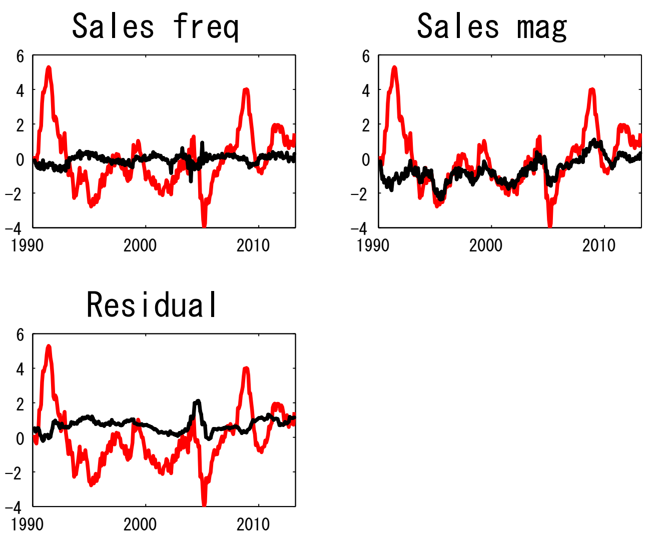



Figure 6: Decomposing Inflation Rate: Temporary Sales Components
Note: A black solid line with dot represents the contribution of each component to the aggregated inflation rate depicted in a red solid line. All series are expressed in a 12-month backward moving sum.

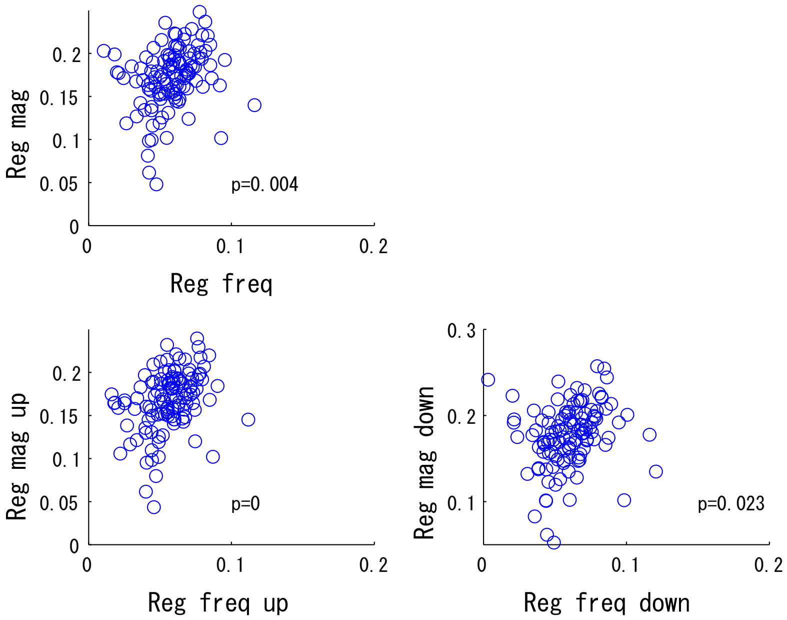



Figure 7: Frequency versus Magnitude of Regular Price Changes

Note: Each dot represents the frequency and magnitude of regular price changes for each 3-digit code item. A number with p in the graph indicates a p-value for the null hypothesis that the two variables are uncorrelated.

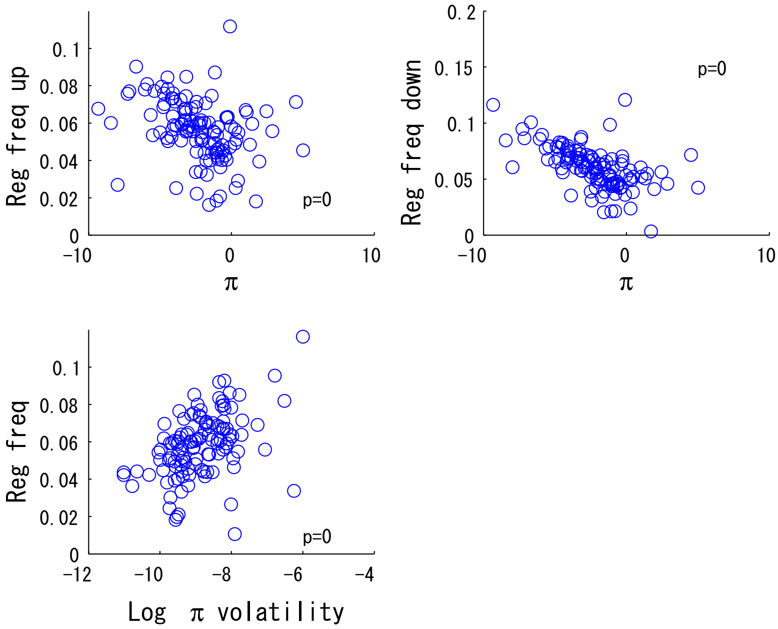



Figure 8: Correlation with Frequency and Inflation Rate

Note: Each dot represents 3-digit code item. A number with p in the graph indicates a p-value for the null hypothesis that the two variables are uncorrelated.

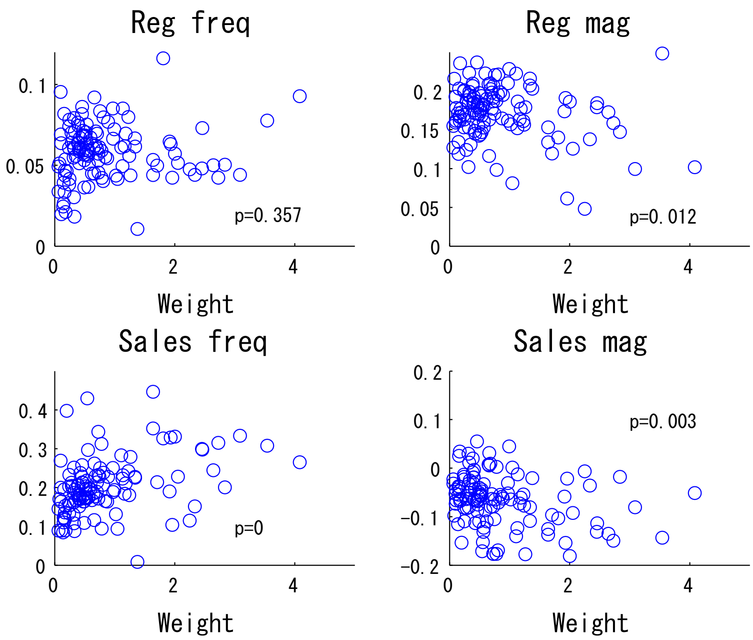



Figure 9: Correlation with Weight

Note: Each dot represents 3-digit code item. A number with p in the graph indicates a p-value for the null hypothesis that the two variables are uncorrelated.

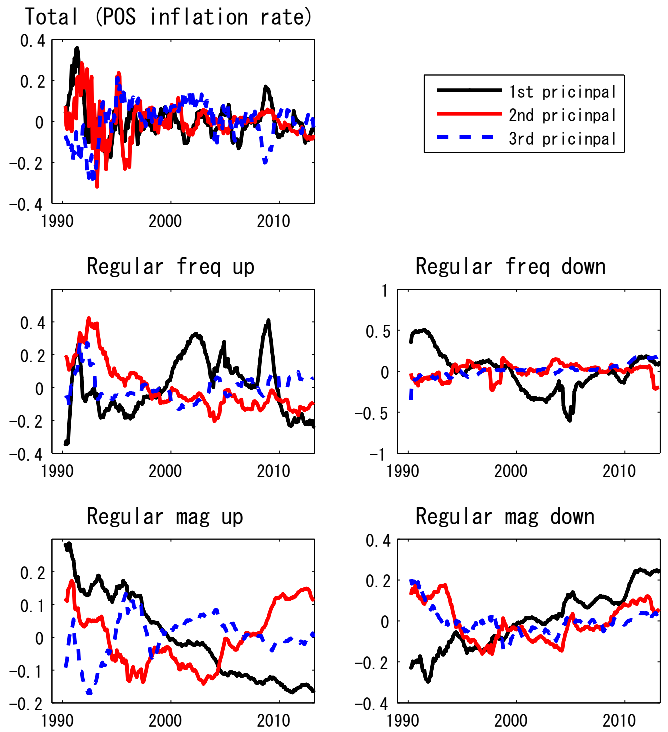



Figure 10: Principals for Total and Regular Price Components
Note: All series are expressed in a 12-month backward moving sum.

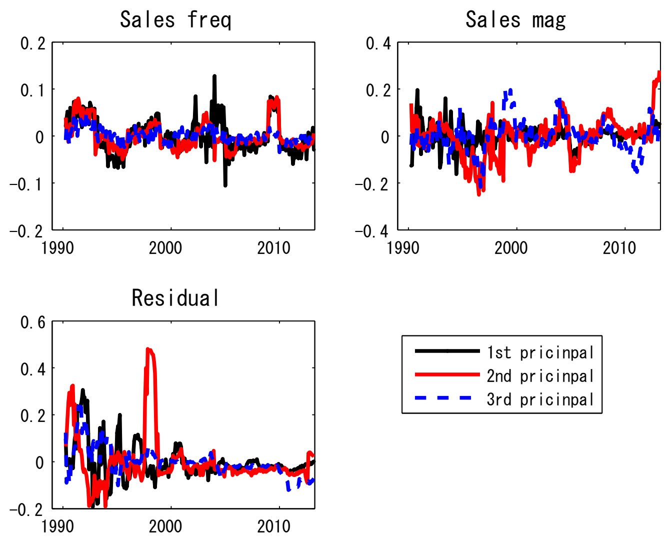



Figure 11: Principals for Temporary Sales Components
Note: All series are expressed in a 12-month backward moving sum.