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Measuring Inflation Expectations: Consumers' Heterogeneity and Nonlinearity*

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ABSTRACT

Using the results of detailed random experiments, we find clear evidence of the effects of information provision on consumers' inflation expectations. The responses of expectations to new information are nonlinear, including those of a sizable share of individuals who do not change their expectations. We document that the updates of consumers are quite heterogeneous, leading to a varied extent of revisions in the face of new information. One possible interpretation is the heterogeneity in consumers' knowledge of inflation-related issues, as well as the difference in the content of the information. Consumers learn and update their expectations vis-à-vis future inflation based on new information, through a mechanism that is more complex than a simple learning model.

Keywords: Inflation expectations, Information, Heterogeneous updating, Nonlinearity, Survey experiments.

JEL Classifications: E31, C81, D80.

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1. Introduction

Expectations vis-à-vis future inflation have an essential role in a variety of economic decisions. Occasionally, such expectations become central to policy debates, because the effectiveness of some types of monetary policies crucially depend upon how such expectations are formed (Blinder, 2000; McCallum, 1984; Sargent, 1982). In spite of their long history, inflation expectations have also been renowned for being difficult to measure. Simply asking people about the future rate of inflation would provide us with quite heterogeneous and unstable results that frequently diverge widely from the actual inflation rate (Mankiw et al., 2004; Schwarz, 1999).

Measuring inflation expectations accurately is of particular importance when economies fluctuate in line with business cycle stages; it becomes even more significant when monetary authorities adopt active monetary policy—such as quantitative easing—because the main transmission mechanism is its expectation channel (Eggertsson and Woodford, 2003). This study investigates how consumers form their inflation expectations, while taking into special consideration their heterogeneity; we do so through the use of Japanese survey data. In this study, we leverage the advantages inherent in a large sample size, in tandem with the use of detailed random experiments; we also consider heterogeneity and nonlinearity in the respondents' updating behaviors. Our estimation results are basically consistent with those of previous studies, but we derive much richer results in terms of the number of statistically significant determinants. We suspect that, like our survey design, Japan's case gives us several significant advantages in terms of investigating inflation expectations: after decades of a long-lasting deflationary period, the rate inflation began to increase in Japan, which pushed people to think about future inflation seriously.

In the heated debate on the formation process of inflation expectation, numerous studies have addressed whether inflation expectations are consistent with the rational expectations hypothesis—and, if they are not, what kind of constraints agents typically face. Full-information rational expectations (Muth, 1961), in which agents immediately process all-new information, have been rejected in many contexts.[1] Instead, more recent models focus on the importance of limitations in acquiring and processing the information that rational agents face (Carroll, 2003; Mackowiak and Wiederholt, 2009; Mankiw and Reis, 2002; Sims, 2003). These models commonly predict that in forming expectations, agents respond more gradually to a shock than the variable being forecasted because of some information rigidity. Many studies rely on survey data to assess such imperfect information models, and they do so by focusing on the cross-sectional dispersion of expectations or aggregate forecast errors (Andrade and Le Bihan, 2013; Branch, 2007; Coibion and Gorodnichenko, 2012b).

The current study fits into a broad research agenda that aims to collect new survey data to better

[1] For the most recent work on this issue, see Coibion and Gorodnichenko (2012a).

measure and understand how agents form and update their subjective expectations about macro-level economic variables of interest (Eusepi and Preston, 2011). Our study builds on recent work by Armantier et al. (2014) and Cavallo et al. (2014), which employs survey experiments that feature information provision in order to examine inflation expectations. As in these studies, we randomly provide individuals with information related to future inflation. We aim to examine the treatment effects on the distribution of inflation expectations to infer how new information received by the respondents influences their updating behavior through a learning process. To assess the role of new information, as in Armantier et al. (2014) we measure the *ex ante* "informedness" of respondents on inflation-related issues by estimating the gap between the true measures and subjective prior beliefs on these issues. We expect that rational consumers who receive the information update their expectations in proportion to the size of this gap.

Compared to previous studies, the approach we employ in this study differs in the two following respects. First, because we take advantage of a large sample size, we carefully design a survey to provide several different kinds of information and examine the robustness of the influence of information treatments. Second, in modeling updating behaviors, we explicitly take into account the behaviors of people who do not reflect on new information, while assuming nonlinearity among them.

We summarize our three main findings thus. First, consumers update inflation expectations in a responsive manner when they face new information. Consistent with previous studies, our estimation results show that there is a systematic relationship between the provision of information and the updating of expectations. Furthermore, we detect a certain influence even among individuals who are not provided with exact figures of inflation-related information. For example, people will react even to mere keywords such as "Bank of Japan" and "price change of ice cream."

Second, people respond to provided information nonlinearly. A sizable proportion of respondents do not change their expectations, even after the provision of new information. Therefore, the data are more consistent with the model that explicitly considers the region of revisions around zero—in which respondents would actually not shift their expectations—than with a simple linear model. The performance of the model varies, depending on the information treatment; this finding can be interpreted in terms of the relevance or reliability of the information for the respondents in forming inflation expectations.

Third, detailed analysis with a large sample reveals several new characteristics of updating behaviors. Variation in provided information leads to a varied pattern of influence on the updates of expectations. Not only the inflation outlook formally published by specialized institutions, but also the news on future price changes in specific grocery items obviously affect consumers' updates of inflation expectations. In addition, such an influence can be accelerated among consumers who are not overly well informed about issues related to inflation.

This paper is organized as follows. Section 2 describes the experimental design. Section 3 provides an overview of the results of the survey experiment and introduces hypotheses on the formation of expectations. Section 4 analyzes individuals' updating behavior vis-à-vis their inflation expectations upon being provided with information; it also discusses the implications of the results in section 3 in terms of modeling the formation of consumers' inflation expectations. Section 5 provides a brief summary and prospects for future research.

2. Experimental design

In this section, we describe the experimental framework that serves as the basis of the following empirical analysis. This framework builds on those found in the literature—in particular, that used by Armantier et al. (2014). Our data were captured through an original survey conducted over the internet near the end of January 2015 (i.e., January 23–February 2). Our target population consists of individuals aged 20–69 registered as survey respondents with one of Japan's major private survey companies.[2] In total, 21,374 individuals were selected from these survey respondents, based on the Population Survey 2010 in terms of gender, age, marital status, and regional compositions. From these individuals, a total of 14,426 participated in the survey (response rate: 67.5%). Each study subject was randomly assigned to one of six information groups, and the members of each group were further randomly subdivided into two groups: 75% of the members were designated as a "treatment group," and 25% as a "control group." Each treatment group contained 1,750–1,800 responses, depending on the response rate; each control group, meanwhile, contained around 600 responses.

Our innovations in terms of the experimental framework are summarized as follows. First, we create six groups of individuals provided with different types of public information vis-à-vis future inflation, and second, these six groups are roughly categorized into two types. The first type is provided with inflation outlook information published by professional institutions (i.e., government, the Bank of Japan [BOJ], or professional forecasters[3]), and the second type is provided through company news releases with regard to planned price increases in specific grocery items. These items include noodles, frozen meals, and ice cream—three items all quite familiar to and frequently purchased by consumers, notwithstanding their attributes.[4]

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[2] The data source is the "Survey of Consumers' Inflation Expectations and Learning." This survey was conducted by INTAGE, a Japanese market research firm, as a contract survey sponsored by Hitotsubashi University.

[3] The outlook vis-à-vis the future inflation rate, generated by around 40 professional forecasters in the private sector, is surveyed and published each month by the Japan Center for Economic Research.

[4] According to the "Household Expenditure Survey (2014CY)," the ratio of expenditures for noodles (i.e., Chinese noodles, cup noodles, and instant noodles) to that for all groceries was 0.98%, and its purchase frequency was 3,592 per 100 households. With regard to frozen meals and ice cream (i.e., ice cream and sherbet), these figures are 0.60% (1,524) and 0.82% (2,220), respectively.

The basic structure of the experiment is as follows (Figure 1).

1. Eliciting inflation expectations from each subject (first question on inflation expectations)

In the first stage,[5] all respondents are asked to provide their expectations of the future inflation rate over the upcoming 12 months for the overall economy. The question is with regard to their "expectations for the rate of inflation/deflation going into the upcoming 12 months." Respondents can choose to provide either a point forecast (as a percentage figure) or a range forecast (the upper/lower limits as percentage figures). In this survey, we define "price levels" as those of the goods and services usually purchased by the respondents and which contain consumption taxes.[6]

2. Eliciting the prior perceptions of the information related to future inflation developments (subjective priors)

In the second stage, respondents are randomly asked one of six questions about either the inflation outlooks of professional institutions or scheduled price changes of particular grocery items (see the Appendix for the details), either of which can measure their *ex ante* knowledge about information that is expected to be pertinent to future inflation. With regard to this question, respondents are asked to provide only point forecasts.

It is worth noting that before the survey periods, there were surges in the prices of raw materials (e.g., wheat, milk, etc.) and in energy prices, partly because of a yen depreciation, and these generally increased commodity prices. As there have been many announcements with regard to increases in the prices of goods that are frequently purchased or with which households are familiar, we expect these announcements to affect people's expectations of future inflation in the overall economy.[7]

3-1. Providing subjects in the treatment group with true measures of the aforementioned information, which would constitute a signal to the subject in the formation of expectations; in the case of the control group, the subject receives no signal (information treatment)

3-2. Eliciting inflation expectations from each subject again (second question on inflation expectations)

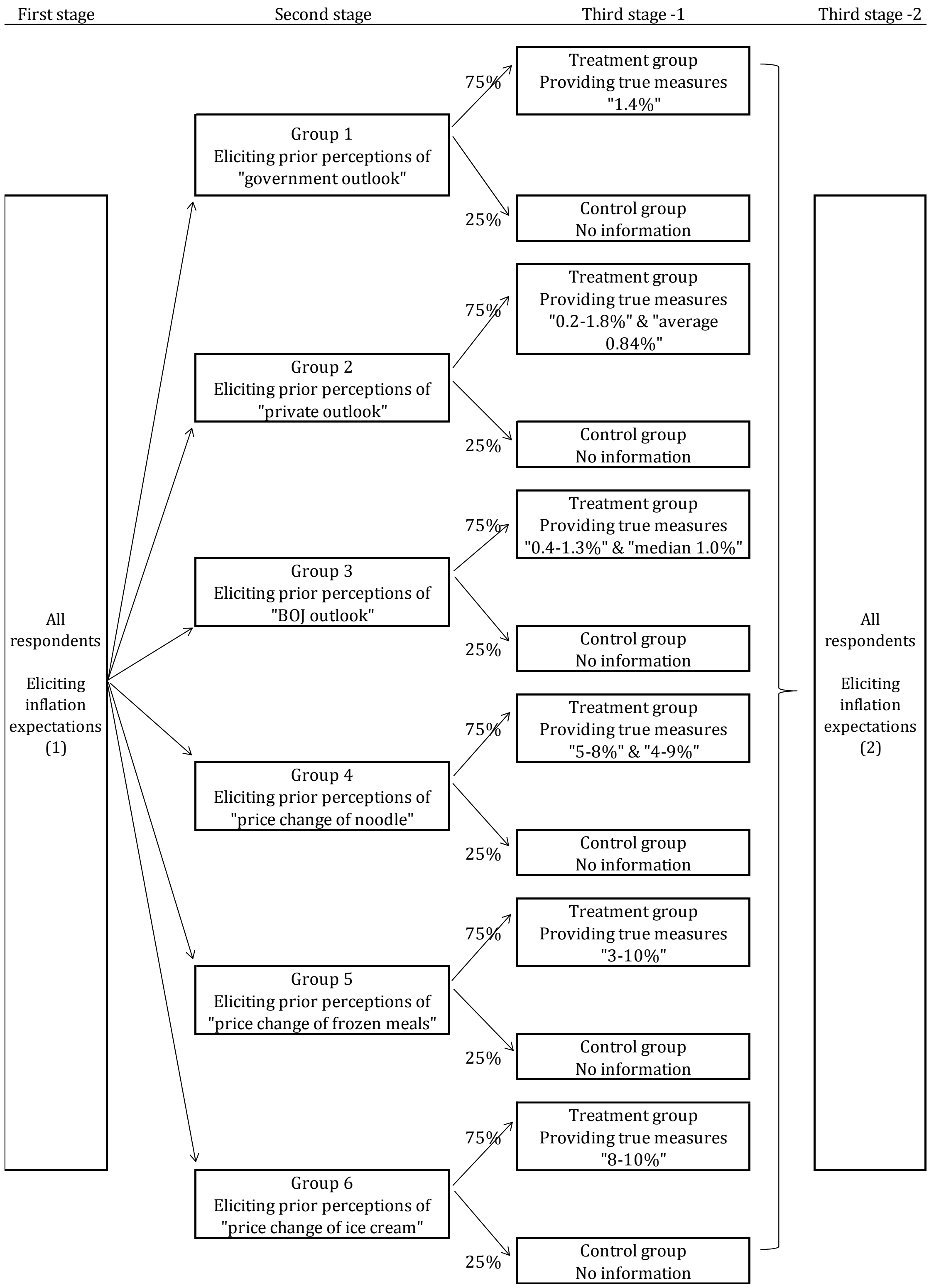
In the final stage, respondents are again asked to provide their views on the future inflation level. The question at this stage is exactly the same as the question posed in the first stage. Note that only respondents in the treatment groups are provided with the correct answer to

[5] Before this stage, we elicited from each subject his or her perceptions of current inflation (i.e., experienced price changes) with regard to specific items (i.e., expected annual inflation rate over the preceding 12 months); this served as an introduction meant to call respondents' attention to the issue of inflation.

[6] The consumption tax rate was 8% at the time of the survey. In April 2014, it increased from 5% to 8%.

[7] The prices of instant noodles, some frozen foods, and ice cream have all shown increasing trends since around mid-2013, according to both the consumer price index (CPI) and the wholesale price index. The year-on-year price increase rate remained positive; this occurred for the first time since 2009. The prices of raw materials (e.g., wheat, meat, or milk) and of products at the wholesale level move in a manner consistent with prices at the retail level.

Figure 1 Flow chart of the experiment



the question posed in the previous stage: those in the control groups are not provided with true measures. More precisely, respondents under treatment are provided with true measures, as described in the Appendix.

3. Overview of survey respondents and survey responses

3.1 Summary statistics

Table 1 contains descriptive statistics with respect to both the respondents' basic attributes and their responses, by group. These statistics are the mean values of the respondents who provided all the information represented in the table. As we randomly assigned the subjects to six groups, the attributes are mostly similar among groups.

Among these 14,249 respondents, 48.4% are women, 35.2% are single, and 45.6% had a university-level or higher level of education attainment. The interquartile range of the household annual income per capita is JPY1.58–3.12 million. The average number of household members is 2.85, with 0.47 children aged 17 or younger.

Table 1 Mean values of responses and respondents' attributes

		Group					
	All	1	2	3	4	5	6
Treatment group	0.749	0.750	0.747	0.747	0.753	0.754	0.744
Perception gap*	1.941	2.894	3.636	2.924	1.405	1.423	-0.622
Inflation perception (average of 6 items)	6.831	6.835	6.727	6.769	6.632	6.795	7.109
Inflation expectations** (before T***)	6.604	6.573	6.705	6.532	6.516	6.768	6.532
Inflation expectations** (after T)	5.761	3.975	4.080	3.731	7.437	7.571	7.762
Updated expecations	0.691	0.744	0.758	0.733	0.634	0.634	0.643
Female	0.484	0.477	0.488	0.477	0.487	0.497	0.481
Mortgage	0.272	0.263	0.282	0.267	0.278	0.269	0.271
Age (20s-30s)	0.363	0.354	0.361	0.355	0.371	0.374	0.365
Age (40s-50s)	0.433	0.450	0.437	0.441	0.433	0.418	0.422
Age (60s)	0.203	0.196	0.203	0.204	0.196	0.208	0.213
Not married	0.352	0.360	0.343	0.351	0.365	0.341	0.349
Household annual income per capita (JPY)	254.2	258.1	254.1	256.4	254.0	246.8	255.6
Education (high school or below)	0.259	0.256	0.274	0.266	0.259	0.255	0.247
Education (college)	0.284	0.295	0.265	0.279	0.293	0.302	0.270
Education (university or above)	0.456	0.449	0.461	0.455	0.448	0.442	0.483
Number of family members	2.845	2.815	2.843	2.841	2.853	2.872	2.842
Number of children (17 years old or younger)	0.468	0.463	0.470	0.484	0.451	0.487	0.453
Number of observations (N)	14,249	2,356	2,364	2,395	2,396	2,382	2,356

* Perception gap= (subjective information prior)-(true measure of treatment information)
** Range responses are transformed into point estimates by taking mid-values of the ranges.
*** T stands for information treatment.

The average perception-gap level—defined as the subjective prior information minus the true measure of treatment information[8]—is positive (1.9%pt) and is greater in Groups 1–3 than in Groups 4–6. In fact, the average gap in Group 6 is negative. The average level of inflation perception among six grocery items[9] during the preceding year is 6.8%, which is well above that in the official CPI statistics. The average level of inflation expectations (prior to the information treatment) is around the same level (6.6%) and correlates positively with the inflation perceptions to a certain extent (0.274, significant at the 1% level). The average level of the respondents' expectations (after the information treatment) is lower (5.8%), although this level does vary across groups to a great extent. As the expectations before treatment are all at similar levels, this result indicates that the treatment affected respondents' expectations in a varied manner, depending on the content of the information. On average, a majority of the respondents updated their expectations after the information treatments (69.1%); a greater share of the respondents updated in Groups 1–3 (higher than 70%) than in Groups 4–6 (lower than 65%).

3.2 Comparison of treatment and control groups

We expect that both subjective priors and inflation expectations before information treatments are drawn from the same distribution for the treatment and control groups in each group. We test this hypothesis as null. Table 2 shows the results of an ES characteristics function test; they indicate that the null hypotheses cannot be rejected for any group with regard to both subjective priors and expectations before treatments. This result clearly shows that both subjective priors and expectations before treatment are comparable between the treatment and control groups of each information group, and this is indicative of successful randomization across groups.

Table 2 Result of ES characteristic function test

	Group					
ES test p-value	1	2	3	4	5	6
Inflation expectations (before information treatments)	0.531	0.145	0.641	0.102	0.355	0.983
Subjective priors of treatment information	0.140	0.509	0.665	0.828	0.757	0.784

Figure 2 compares the distributions of inflation expectations following information provision, between the treatment and control groups of Groups 1–6. We can clearly see differences in the distribution between the treatment and control groups. Interestingly, the distribution of expectations in the control groups clearly differs among Groups 1–6; this implies the possibility that respondents'

[8] For Groups 2–6, we set the true measures as a range, rather than an exact figure (e.g., 8–10%, see the Appendix for details). For these groups, we regard the perception gaps as zero if the subjective priors are within this range; otherwise, we employ the closest end of the band to subjective priors to derive perception gaps. Therefore, the share of zero-level perception gaps is higher if the band of the true measures is wider (i.e., Group 5).

[9] These six items consist of 1) milk, 2) vegetable and fruit juice, 3) ice cream, 4) sausage, 5) cheese, and 6) bottled green tea.

expectations can be influenced by particular inflation-related keywords (e.g., “BOJ,” “scheduled price change of noodles”), even when they are not informed of true measures. Possible interpretations are that people are either 1) quite sensitive to these keywords, assuming a certain prior knowledge of what they imply, or 2) simply reactive to the information provided right before being asked about their expectations, without judging whether the provided information is really important to the future development of inflation. While this is an interesting issue in investigating the formation of inflation expectations, we do not discuss this issue further in this study.

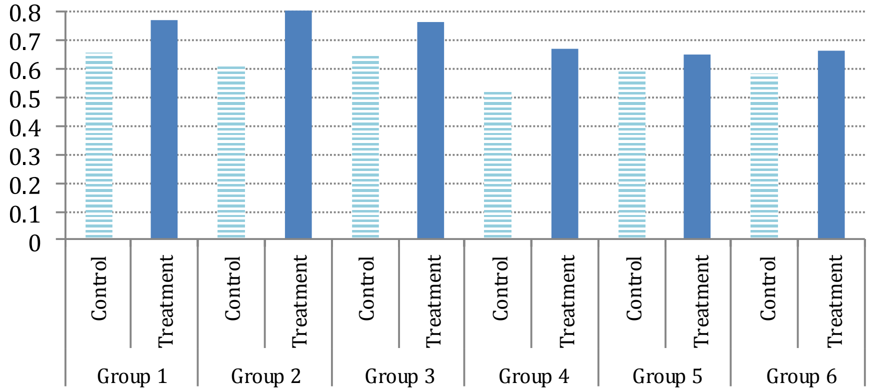
Figure 2 Inflation expectations after treatments (by group and by information treatments)

3.3 Impact of treatment information on inflation expectations

3.3.1 Revisions of expectations

As explained, twice in this survey we ask each respondent to provide his or her views on future inflation. Although we pose several questions not directly linked to inflation expectations and also provide information treatments between the two questions, the survey respondents do answer the exact same questions within a short time interval. However, the proportion of individuals who updated their expectations in response to the second question is surprisingly high: at least a majority of the respondents in each group changed their views (Figure 3). As these proportions are higher among the treatment groups than the control groups, we argue that information provision should influence expectations, particularly when people consider that information reliable and relevant vis-à-vis future inflation developments.[10] Concurrently, we note that the shares of updates are fairly high among the control groups; in particular, the differences between the control and treatment groups are limited in Groups 5 and 6.

Figure 3 Proportion of respondents who updated their expectations after information treatment, by group



In subsection 3.3.2, we examine the factors that possibly influence these expectation updates.

3.3.2 Perception gaps and inflation expectations

Our first hypothesis predicts that information provision induces the updates of inflation

[10] We tested a hypothesis that our treatment (i.e., information provision) induces respondents to change their expectations from the first question to the second one, via Probit analysis with a control of respondents' attributes. The estimation results clearly indicate the positive impact of treatment on the probability of updates for all six groups.

expectations.[11,12] As all the provided information is publicly available, this hypothesis implies a rejection of full-information rational expectations for an average respondent. In the following subsections, we present some reduced-form evidence of the manner in which individuals react to randomly assigned information. From the result of nonparametric analysis, Armantier et al. (2014) argue that one should expect a linear relationship between the revision in expectations and the relative importance of information to individuals. Based on their framework, we also consider a hypothesis regarding how the importance of treatment information for respondents relates to their updating behavior.

In this subsection, to consider the relative importance of the provided information, we define the difference between the respondents' subjective priors about the treatment information (τ) and the true measure of the treatment (τ^*) as a perception gap, in line with discussion in the literature. As this gap becomes smaller in absolute terms, we assume that the agent becomes more informed about the future development of inflation. If respondents are already fully informed about the true values of the treatment information, this perception gap should be equal to zero. In this case, the information treatment would not influence the expectations, as it is already reflected in them. Otherwise, as the respondents' subjective priors diverge from the true measures, the provided information should be recognized as a more important one that should be reflected in the expectations.

Specifically, the perception gap of respondent *i*, (PG_i), is defined as follows:

$$PG_i = \tau_i - \tau^*.$$

This perception gap is one of the key concepts in our study. We expect that less-informed respondents would update their inflation expectations to a greater extent by using this treatment information. The expected sign of the correlation between gaps and revisions is negative: if an individual realizes his or her prior was too high (i.e., a positive perception gap), he or she will lower the expectation, and vice versa.

For the sake of the discussion that follows, we define a revision of expectations as follows.[13]

$$\Delta\pi_i^E = \pi_{is}^E - \pi_{if}^E,$$

[11] In previous studies, the updating process is sometimes documented as a strong linear relationship between inflation expectations and perceptions of past inflation (Jonung, 1981).

[12] Recent studies—including that of Cavallo et al. (2014)—highlight the importance of the role of personal consumer experience in the formation of inflation expectations. It is true that in our survey, the majority of respondents selected "personal shopping experience" as the background of their inflation expectations. As our dataset involves precise information of pertaining to experienced inflation among six major grocery items, as well as respondents' perceptions of experienced inflation, we can examine the relationships between experienced and perceived inflation rates. As a result, we find perceived inflation to be quite inaccurate. Furthermore, it correlates with inflation expectations prior to information treatment to a certain extent, but not so with those after treatment with any statistical significance. Thus, we do not use in our analytical framework information on personal inflation experience.

[13] In the estimation of revisions, we employ the mid-values of inflation expectations if a respondent provides a range forecast rather than a point forecast.

where $\Delta\pi_i^E$ stands for the revision of expectations of individual i, π_{if}^E is the expectation of i from the first question (i.e., before information treatment), and π_{is}^E is the expectation of i from the second question (i.e., after information treatment).

Figure 4 is a scatterplot of perception gaps and revisions by group. There seem to exist positive rather than negative correlations between revisions and perception gaps (correlation 0.185, p-value 0.000). Although we observe an opposite sign, the correlation among those in a treatment group is apparently smaller than that among those in a control group (correlation 0.149 and 0.308 respectively, p-values are both 0.000). This indicates the possible influence of our treatment, which may work to "cancel out" the originally observed positive relationship between gaps and revisions.

Figure 4 Relationship between perception gaps and revisions, by group

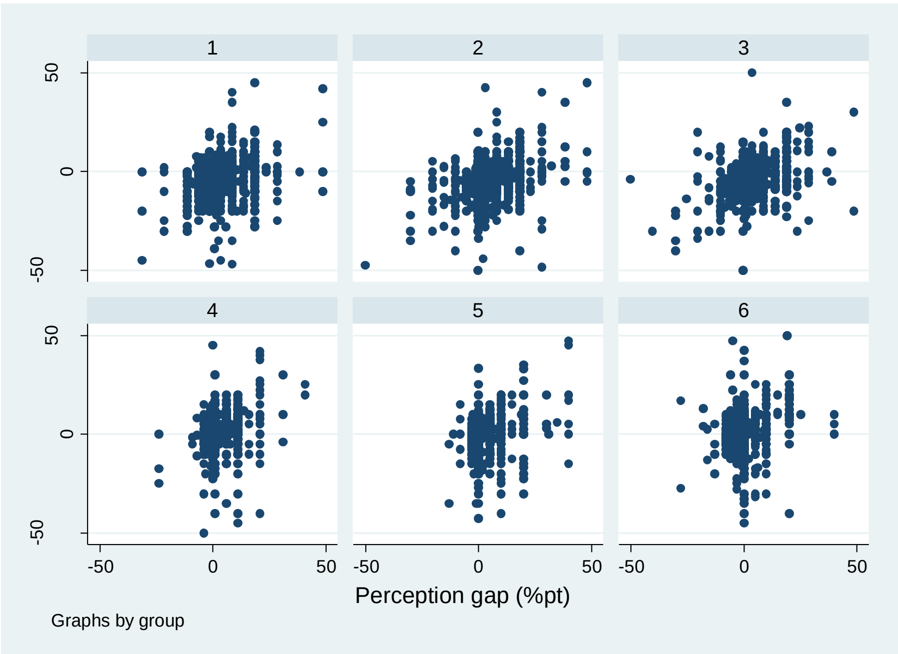


Table 3 provides summary statistics of the revisions by information treatment. The mean revisions are negative for Groups 1–3 and positive for Groups 4–6. The median revisions are zero, save for those under treatment in Groups 1–3. The absolute values of the mean revisions of the treatment groups are greater than those of the control groups in any of the six groups, thus indicating the possible impact of the treatment information on revisions. The fourth column of Table 3 shows the proportion of respondents who did not change their expectations in the second question. Although their perception gaps are not necessarily zero, a sizable proportion of respondents—not only among the control groups, but also among the treatment groups—did not shift their expectations. This finding is not consistent with our previous presumption that assumes a negative correlation between perception gaps and revisions. Indeed, Figure 4 shows that there is a mass of observations around the origin, where the relationship between gaps and revisions are quite ambiguous. We thus expect that respondents do not update their expectations unless they find the provided information to be sufficiently important. In other words, there exists a sort of "inaction interval" for the revision of expectations, within which the respondents' expectations remain unchanged.

The literature discusses the conditions under which agents update their expectations (e.g., Mankiw et al., 2004). In this study, however, we do not intend to impose any particular learning rule or information-processing rule, as seen in previous studies. However, we do consider that information stickiness[14] might not be consistent with our survey results, which contain a fair proportion of respondents who do not update their expectations, even when treatment information is readily available to them at no particular fixed acquisition cost.

Table 3 Summary statistics of revisions by group and information treatment

		revision				
		mean	sd	median	proportion of those w/o revision	N
Group 1	Control	-1.623	5.439	0	34.3%	589
	Treatment	-2.923	8.480	-2	22.7%	1,769
Group 2	Control	-1.539	8.706	0	38.6%	598
	Treatment	-2.993	7.018	-2.5	19.3%	1,767
Group 3	Control	-1.525	6.147	0	35.4%	605
	Treatment	-3.232	6.554	-2.5	23.8%	1,791
Group 4	Control	0.898	6.705	0	47.9%	591
	Treatment	0.928	6.692	0	32.9%	1,805
Group 5	Control	0.757	5.949	0	40.6%	586
	Treatment	0.819	6.744	0	35.3%	1,796
Group 6	Control	0.647	6.995	0	41.7%	604
	Treatment	1.431	7.146	0	33.6%	1,754

In summary, the key hypotheses to be tested in this study are as follows.

[H1] In the treatment groups, the expectations of the respondents are influenced in a systematic manner by perception gaps. If subjective priors turn out to be too high (low) (i.e., positive [negative] perception gaps), respondents will change their expectations in a downward (upward) direction.
[H2] Respondents remain inactive unless they recognize a need for a sufficient change to the expectations they made prior to the information treatment. In other words, there are revision thresholds that designate the point at which respondents will not change their expectations, despite having received some new inflation-related information.

[14] A sticky information model considers the problem of an economic agent who faces a fixed cost in acquiring and processing new information. In the presence of such costs, it becomes optimal for the agent to update his or her information infrequently (Reis, 2006).

4. Analysis of updating behavior

In this section, we undertake a parametric analysis of updating behavior. We start with a simple ordinary least squares (OLS) model, and assume there are no inaction areas for the respondents. From H1, we expect revisions to inflation expectations to relate negatively to perception gaps. We consider two estimation specifications.[15] In Model (1), we consider a simple linear relationship between the revisions and perception gaps. Model (2) adds quadratic terms of perception gaps to Model (1), to examine whether the influence of the gaps accelerate with their absolute values. Table 4 summarizes the estimation results of both models, based on the wild bootstrap.[16]

To be precise, we estimate the following regressions separately, for each of the six groups:

$$\Delta\pi_i^E = X\beta.$$

In Model (1), this is described as

$$\Delta\pi_i^E = \alpha^1 + \beta_1^1 PG_i + \beta_2^1 T_i + \beta_3^1 (T_i * PG_i) + \varepsilon_i^1. \tag{1}$$

In Model (2), this corresponds to

$$\Delta\pi_i^E = \alpha^2 + \beta_1^2 PG_i + \beta_2^2 T_i + \beta_3^2 (T_i * PG_i) + \beta_4^2 (PG_i)^2 + \beta_5^2 (T_i * PG_i)^2 + \varepsilon_i^2. \tag{2}$$

T_i is an indicator that equals 1 if respondent *i* is in a treatment group, and 0 otherwise. ε_i is an error term. α^j and β_k^j (j = 1,2 and k = 1,…,5) are parameters to be estimated. If a respondent's perception gap is zero, the average revision is α^j for a control group and $(\alpha^j + \beta_2^j)$ for a treatment group. β_2^j captures the extent of the average revisions that are attributable to treatment groups but which are not explained by perception gaps. We do not have any anticipated signs for the parameters (α^j, β_2^j), which may vary depending on the information provided. β_1^j describes a baseline relationship between perception gaps and revisions. The parameters $(\beta_3^j, \beta_4^j, \beta_5^j)$ are the coefficients of our main interest. If β_3^j is estimated to be statistically significant, this provides an estimate of the causal effect of information treatment on revisions through perception gaps. β_3^j is expected to be negative, based on H1. (β_4^j, β_5^j) allows the possibility of an acceleration in the slopes with regard to the absolute perception-gap levels.

[15] Besides these two specifications, we also consider a model that incorporates the idea of asymmetric response towards over and under-perceptions. However, we do not adopt this specification, since such an asymmetric property, if there is any, could be captured by including the quadratic terms of perception gaps.

[16] We employ the wild bootstrap, which can be used to obtain heteroskedastic-consistent standard errors for both OLS and NLS estimates (Hausman and Palmer, 2012; Horowitz, 2001).

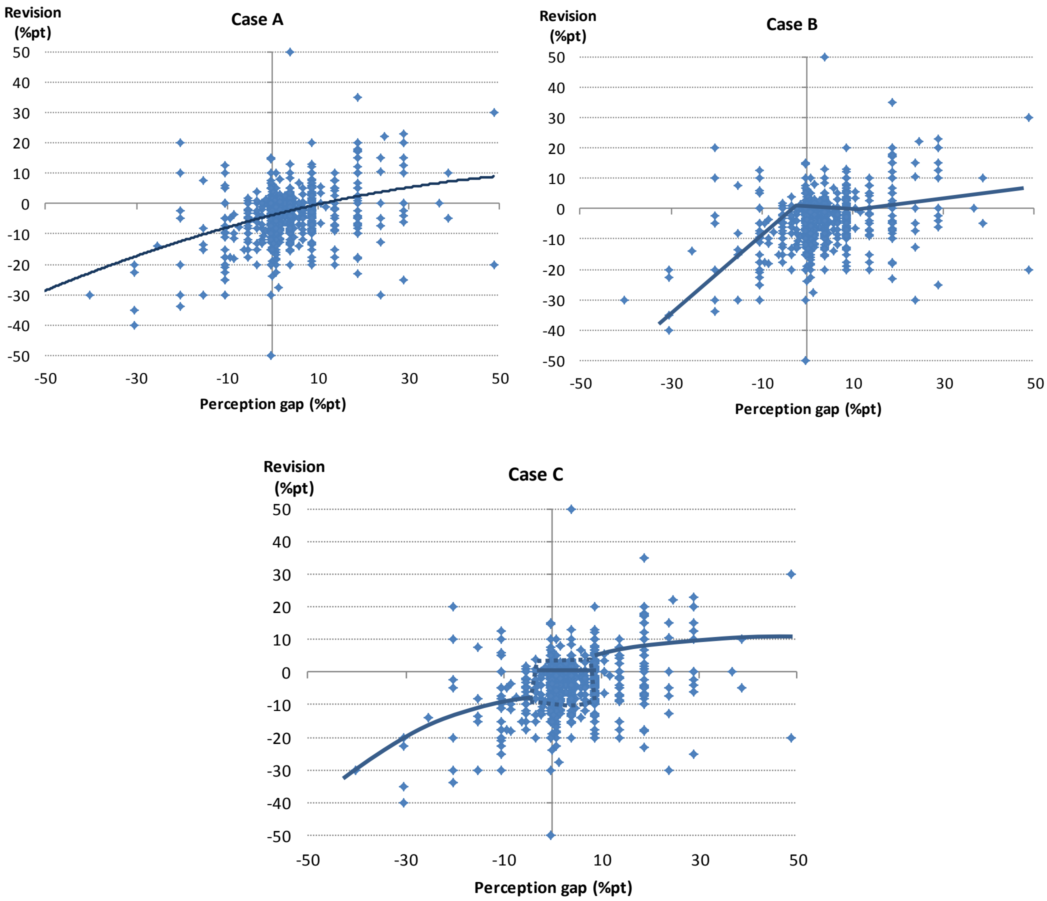
The first row of Table 4 shows the estimates of β_1; all are positive and significant, except in Model (2) of Groups 4 and 5. As indicated in Figure 4, individuals with higher subjective priors tend to make greater revisions. Furthermore, the coefficients of an interaction term between the perception gap and treatment are estimated to be negative and significant only in limited cases. In Model (1), they are negative for Groups 2–5 (with a significance level of only 10%, save for Group 2), while they are negative only for Group 2 in Model (2). Although the signs of β_3^j are consistent with our expectations, the net impact of the perception gap on revision (i.e., $\beta_1^j + \beta_3^j$) is positive across all groups. This implies that, according to the OLS results, the treatment effect through perception gaps seems to exist to a certain extent, but it is rather limited.

By using the results of Model (2), we next examine how the treatment effect evolves with perception gaps (Figure 6, dotted line). The coefficients of the interaction terms ($(T_i * PG_i)$ and $(T_i * PG_i)^2$) are estimated with statistical significance only for Group 2. For the other groups, the impact of the treatment is estimated as constant or zero, notwithstanding the perception-gap level. In Group 2, the treatment effect shows a quadratic curve, with its bottom at around 8%pt of the perception gaps. For example, respondents who replied that the inflation outlook of private forecasters is "10%" will, on average, revise their inflation expectations by ▲2.46%pt after recognizing that the outlook is actually "1.8%." The treatment effect is positive if the perception gaps are negative and sufficiently small; for example, among individuals who expected the private inflation outlook to be "▲12%," the average treatment effect is 3.64%pt. From the figure, we see that the impact of negative perception gaps accelerates as the gaps expand. In contrast, in Group 1, the information treatment drives down expectations by ▲2.1%pt on average, regardless of the respondents' perception gaps. In Group 6, the information treatment pushes up the expectations by 0.87%pt on average, regardless of the respondents' perception gaps. It is intuitive to interpret that opposite signs among these treatment effects are linked to the level of perception gaps; most of the respondents in Group 1 have positive perception gaps (72.1% of the respondents over-estimate government outlook), while most of the respondents in Group 6 have either negative or zero gaps (14.8% of the respondents over-estimate the scheduled price increase in ice cream). From the OLS results, we determine that the respondents with an information treatment learn from the provided information only in a limited manner, and in a way not quite linked to their "informedness."

We next estimate (1) and (2) by nonlinear least squares (NLS)—thus taking account of the importance of the sizable share of individuals who do not update expectations, even after information treatment. In H2, we assume that if the importance of the information is not recognized as sufficient, the respondents will remain "inactive" (i.e., not pay any attention) to the new information; thus, we observe no revisions. As a result, we see both upward revisions and downward revisions as continuous variables, up to some certain thresholds, and we observe a considerable number of observations with zero revisions in between.

Figure 5 summarizes the specifications of our estimation. Case A describes an OLS model, and Case B shows a Tobit model with two thresholds. Going forward, we will discuss an NLS model that corresponds to Case C. We thus introduce an estimation model in which we assume a linear relationship between the revision and several factors, which include the perception gap and its squared term, a treatment dummy, various interaction terms, and an error term (u_i). The basic specification is the same as that in Models (1) and (2) in OLS, and we consider the revision thresholds that best fit our observations. Our specification is similar to that in the Tobit model, and we consider two unknown thresholds of dependent variables.

Figure 5 Specifications describing relationships between perception gaps and revisions



Note: Dots indicate a scatterplot of perception gaps and revisions for Group 3 as an example; lines depict $X\beta$ for each specification.

Our model can thus be described as follows:

$$\Delta\pi^E = m(X, \theta_0) + u, \mathrm{E}(u|X) = 0,^{17} \tag{3}$$

$$m(X, \theta_0) = \begin{cases} X\beta & if\ \Delta\pi^E \geq \tau_1 \\ 0 & if\ \tau_2 \leq \ \Delta\pi^E < \tau_1, \\ X\beta & if\ \Delta\pi^E \ < \tau_2 \end{cases} \tag{4}$$

where X is a set of explanatory variables, which are the same as those in (1) and (2). $m(X, \theta_0)$ is a parametric model of $\mathrm{E}(\Delta\pi^E|X)$, where m is a known function of X and θ_0. $(\tau_{1,}\tau_2)$ correspond to the upper and lower threshold, respectively. As we expect differences in updating behavior between treatment and control groups, we allow these thresholds to vary between the control group (τ_k^C) and the treatment group (τ_k^T) $(k = 1,2)$ in this specification. θ_0 is a parameter vector that consists of a set of thresholds $(\tau_1^C, \tau_2^C, \tau_1^T, \tau_2^T)$, as well as parameters β that are defined in the linear specifications of (1) and (2).

From (3), the NLS estimator of θ_0, $\hat{\theta}$ solves

$$\min_{\theta}[N^{-1}\textstyle\sum_{i=1}^{N}[\Delta\pi_i^E - m(X_i, \theta)]] \, , \tag{5}$$

where N is the number of observations.

When we estimate the thresholds of the inaction region, we look for $(\widehat{\tau_1^C}, \widehat{\tau_2^C}, \widehat{\tau_1^T}, \widehat{\tau_2^T})$ that solves (5) from a range of [–10,10]. This is because most revisions (i.e., 93.9% of the total) concentrate in this region, and so it is not likely that people will remain inactive at some extreme revision values that are beyond this range.

The estimation results of (5) are summarized in Table 5. “Thresholds” describe the estimated thresholds from (5), and the “Bootstrap confidence intervals” at the bottom of the table show the 95% confidence intervals of the thresholds derived from the wild bootstrap. The standard errors of the NLS estimates are bootstrap standard errors. We summarize the main results of the estimation as seen below.

The first point to be noted is a significant improvement in the performance across all models and groups, compared to those in OLS. The sum of squared residuals (SSR) substantially declines from the OLS to the NLS Model (1), save for in Group 2.[18] This provides supporting evidence of our empirical specification by which we set the areas of “inaction” for all six groups. In addition, all the coefficients of NLS Model (2) are estimated with at least the 10% level of statistical

[17] We assume that heteroskedasticity exists, even after dropping several extreme outliers (i.e. observations with absolute value of revisions equal to or greater than 100). Although the revisions concentrate around zero, some respondents actually provide revisions that are quite unlikely in their levels (e.g., 20%pt and over) (see Figure 2), but we consider that, like the others, these individuals may form and update their expectations in a systematic manner. Thus, we employ the wild bootstrap for our estimation.

[18] The SSR of Model (2) of Group 2 is much smaller than that seen in the OLS results.

significance—another notable difference from the OLS results. Furthermore, save for Model (1) of Group 2, the four thresholds are all estimated quite precisely and with narrow confidence intervals.

The differences in SSRs among the six groups offer insights into the degree to which people consider provided information to be a relevant and/or reliable source when forming inflation expectations. The SSRs of Group 3 are by far the smallest for both Models (1) and (2), followed by Group 6. This can be interpreted thus: people trust the BOJ more than the government or private institutions in managing the future inflation developments. It seems also that the respondents were greatly influenced by the ice cream treatment (i.e., Group 6). The SSRs are greater in Groups 4 and 5 than in Group 6, but smaller than those in Groups 1 and 2. Although we ask the respondents for their general views on inflation expectations, it is striking that people seem to be more influenced by the information on the price trends of quite specific items than information on the general CPI outlook (save for the BOJ outlook). In other words, people's expectations can indeed be affected by inflation-related information with respect to specific items that are familiar to them.[19] This result contrasts somewhat with those seen in the literature (e.g., Armantier et al., 2014).[20] These differential results might stem from the 1) difference in the sample size, or 2) difference in the content and variation of the treatment information (i.e., realized trend of food CPI versus future plan of price change for specific food items).

Second, the estimated coefficients are considerably different from those in the OLS results. In general, the NLS coefficients tend to be greater than their OLS counterparts in absolute terms, if both are statistically significant. In other words, the NLS results tend to yield more compelling evidence of the relationship between perception gaps and revisions, as well as that between treatment and revisions.

Third, the NLS results show varied results among the various groups. In Model (1), for all six groups, β_1^1 is positive and β_3^1 is negative, with the resulting positive $(\beta_1^1 + \beta_3^1)$. This result is identical to that in OLS. Therefore, we again interpret this result as the expected effect of treatment, despite its limited extent. On the other hand, in terms of garnering further insights, the NLS coefficients of Model (2) are more complicated. They vary among the various groups, and even carry opposite signs. Figure 6 (solid line) compares the estimated average treatment effects for various perception-gap levels. In general, the estimated treatment effect has a downward slope with respect to perception gaps, which is consistent with H1. This implies that greater perception gaps are linked to smaller revisions. However, the derived signs of the treatment effect are not necessarily consistent

[19] In this survey, we also asked the respondents whether they had purchased ice cream in the one year preceding the survey point, and how much they thought the price of ice cream had changed in the previous year. Among those in Group 6, 84.8% of the respondents had actually purchased ice cream at least once, and their inflation perception was 4.94% on average. Compared to this average, the provided information (8–10%) is appreciably higher; the average subjective prior, meanwhile, is 8.42%.

[20] This study found that information about price changes among food and beverage items have limited pass-through to consumers' inflation expectations.

with H1. With regard to positive perception gaps, the treatment effects are negative at an average level, and this is consistent with our supposition. The exception is Group 5, where the treatment effect turns out to be negative only between the 10%pt and 20%pt perception-gap values, although it does show a clear downward slope. In Groups 4–5, the slopes of the treatment effect become steeper as the perception gaps increase; thus, the effect seems to accelerate if respondents over-perceive the treatment information. As an example, in Group 4, an increase in perception gap from zero by one standard deviation (4.43%pt) leads to a decrease in revision by 1.34%pt. In contrast, negative perception gaps often relate to negative effects, although the extent of these effects are limited (e.g., Groups 1, 3, and 6). In Groups 2 and 5, the estimated treatment effects are positive for negative perception gaps, and this is consistent with our hypothesis. The downward slope of the treatment effects with regard to negative perception gaps is notably steep in Group 2, implying that a decrease in perception gap from zero by one standard deviation (i.e., ▲6.87%pt) leads to an increase in treatment effects by 4.22%pt. In Group 5, however, the positive treatment effect does not accelerate as the perception gaps become smaller.[21]

We note that the estimated treatment effects remain flat—notwithstanding the perception-gap level—if we estimate these effects on the basis of the OLS results (Model (2)), except for Group 2.

Furthermore, the thresholds for the inaction regions have different patterns between Groups 1–3 and Groups 4–6. In Groups 1–3, both the left-hand-side and right-hand-side thresholds are estimated as being much greater than those in Groups 4–6. Interestingly, we find no substantial differences in the inaction regions between the treatment and control groups, save for in Group 5. This may actually suggest that "inaction" is not so influenced by precise perception-gap levels; rather, this is linked to the content of provided information (e.g., "increase in familiar food prices" and "inflation outlook by the authority").

[21] For example, a decrease in perception gap from zero by one standard deviation (i.e., ▲4.70%pt) leads to a decrease, and not an increase, in the extent of revision of the inflation expectations, by 0.76%pt.

Table 4 Baseline regressions (OLS, wild bootstrap)

Dependent variable: revision (Expectation after treatment - Expectation before treatment)

	Group 1		Group 2		Group 3	
	(1)	(2)	(1)	(2)	(1)	(2)
Perception gap (PG)	0.253***	0.323***	0.584***	0.647***	0.480***	0.409**
	(0.0663)	(0.0700)	(0.101)	(0.141)	(0.0840)	(0.160)
Treatment dummy (T)	-0.680**	-2.097***	0.455	-1.295**	-0.401	-1.189***
	(0.330)	(0.292)	(0.595)	(0.632)	(0.400)	(0.443)
PG*T	-0.0845	0.1000	-0.386***	-0.292*	-0.168*	-0.136
	(0.0801)	(0.0950)	(0.108)	(0.153)	(0.0955)	(0.174)
PG^2		-0.00608		-0.0214***		0.000991
		(0.00485)		(0.00815)		(0.00713)
(PG^2)*T		-0.00365		0.0188**		-0.00175
		(0.00553)		(0.00887)		(0.00797)
Constant	-2.548***	-1.999***	-4.114***	-2.775***	-3.604***	-2.715***
	(0.235)	(0.218)	(0.574)	(0.598)	(0.363)	(0.404)
N	2,356		2,364		2,395	
Adj. R-sq	0.024	0.125	0.106	0.128	0.135	0.111
SSR (sum of squared residuals)	114,997	112,935	112,649	110,685	78,681	77,937

	Group 4		Group 5		Group 6	
	(1)	(2)	(1)	(2)	(1)	(2)
Perception gap (PG)	0.461***	0.180	0.429***	0.227	0.387***	0.351***
	(0.154)	(0.114)	(0.0881)	(0.145)	(0.0542)	(0.0597)
Treatment dummy (T)	0.247	0.430	0.280	-0.293	0.0944	0.868***
	(0.233)	(0.268)	(0.234)	(0.265)	(0.256)	(0.289)
PG*T	-0.286*	0.140	-0.255*	0.167	-0.121	-0.0563
	(0.170)	(0.156)	(0.140)	(0.186)	(0.0835)	(0.0783)
PG^2		0.00952		0.00195		-0.00385
		(0.0115)		(0.00735)		(0.00655)
(PG^2)*T		-0.00997		-0.0104		-0.00395
		(0.0145)		(0.00919)		(0.00707)
Constant	0.407**	0.289	0.266	0.410*	1.139***	0.857***
	(0.196)	(0.196)	(0.200)	(0.220)	(0.187)	(0.236)
N	2,396		2,364		2,395	
Adj. R-sq	0.044	0.040	0.106	0.128	0.056	0.079
SSR (sum of squared residuals)	100,451	99,749	97,217	96,253	92,026	89,817

*, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Perception gap = (subjective priors about the treatment information) - (true measure of the treatment)

Table 5 Updating and perception gap (NLS, wild bootstrap)

NLS, Wild bootstrap	Group 1		Group 2		Group 3	
	(1)	(2)	(1)	(2)	(1)	(2)
Perception gap (PG)	0.458***	0.508***	0.380***	0.900***	0.693***	0.584***
	(0.059)	(0.057)	(0.116)	(0.130)	(0.059)	(0.057)
Treatment dummy (T)	-1.594***	-1.179***	-0.770	2.018***	-1.926***	-1.765***
	(0.235)	(0.279)	(0.501)	(0.334)	(0.304)	(0.283)
PG*T	-0.050***	-0.050**	-0.127	-0.554***	-0.270***	-0.145***
	(0.018)	(0.023)	(0.124)	(0.139)	(0.063)	(0.044)
PG^2		-0.004*		-0.009***		0.005***
		(0.003)		(0.003)		(0.001)
(PG^2)*T		-0.001**		0.009***		-0.007***
		(0.000)		(0.003)		(0.003)
Constant	-7.009***	-6.932***	-3.132***	-9.922***	-6.746***	-6.816***
	(0.183)	(0.221)	(0.470)	(0.303)	(0.282)	(0.238)
N	2,356		2,364		2,395	
SSR	88,496	87,715	112,649	85,986	53,005	52,781
Thresholds (LT, RT, LC, RC)	(-4.24, 8.58, -3.40, 8.63)	(-3.87, 8.59, -3.41, 8.49)	N.A.	(-3.94, 8.01, -5.24,7.02)	(-4.20,9.52, -5.04,8.73)	(-4.25,9.14, -3.40,8.93)
Bootstrap confidence intervals						
Threshold, LT	[-3.779, -3.772]	[-3.546, -3.538]	N.A.	[-3.472, -3.463]	[-3.666,-3.654]	[-3.665, -3.653]
Threshold, RT	[8.769, 8.809]	[9.386, 9.484]		[9.163, 9.214]	[11.03, 11.08]	[10.15, 10.20]
Threshold, LC	[-3.529, -3.524]	[-3.414, -3.405]		[-4.669, -4.645]	[-3.213, -3.191]	[-2.835, -2.821]
Threshold, RC	[9.532, 9.596]	[9.194, 9.289]		[7.293, 7.340]	[8.394, 8.419]	[8.380, 8.416]

NLS, Wild bootstrap	Group 4		Group 5		Group 6	
	(1)	(2)	(1)	(2)	(1)	(2)
Perception gap (PG)	0.936***	0.541***	0.944***	0.381***	0.398***	0.304***
	(0.122)	(0.103)	(0.096)	(0.106)	(0.065)	(0.047)
Treatment dummy (T)	0.667***	0.824***	7.023***	6.672***	-0.145	0.618***
	(0.178)	(0.292)	(0.302)	(0.270)	(0.090)	(0.150)
PG*T	-0.615***	-0.210**	-0.742***	0.017***	-0.032	0.083***
	(0.133)	(0.104)	(0.129)	(0.005)	(0.024)	(0.030)
PG^2		0.016**		0.022***		0.013***
		(0.008)		(0.003)		(0.004)
(PG^2)*T		-0.016*		-0.031***		-0.024***
		(0.008)		(0.005)		(0.004)
Constant	3.807***	3.640***	-3.443***	-3.235***	5.182***	4.843***
	(0.197)	(0.252)	(0.259)	(0.224)	(0.136)	(0.159)
N	2,396		2,382		2,356	
SSR	83,742	83,520	85,409	84,413	74,757	72,258
Thresholds (LT, RT, LC, RC)	(-10.51, 2.32, -10.55, 2.66)	(-10.50, 2.34, -10.16, 1.15)	(-9.03, 1.14, -1.31, 8.49)	(-10.00, 1.51, -1.97, 8.60)	(-10.52, 2.62, -10.26, 2.59)	(-10.63, 2.52, -10.81, 2.61)
Bootstrap confidence intervals						
Threshold, LT	[-11.71, -11.62]	[-14.18, -13.97]	[-10.52, -10.47]	[-11.08, -11.03]	[-12.39, -12.23]	[-12.37, -12.29]
Threshold, RT	[2.276, 2.281]	[2.202, 2.212]	[1.350, 1.357]	[1.548, 1.555]	[2.297, 2.305]	[2.463, 2.471]
Threshold, LC	[-10.65, -10.56]	[-10.26, -10.11]	[-1.145, -1.138]	[-1.913, -1.908]	[-12.00, -11.86]	[-11.82, -11.75]
Threshold, RC	[1.896, 1.913]	[0.998, 1.021]	[8.008, 8.035]	[8.058, 8.082]	[2.620, 2.627]	[2.494, 2.503]

*, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.
Perception gap = (subjective priors about the treatment information) - (true measure of the treatment)
LT=Left threshold for treatment group, RT= Right threshold for treatment group, LC= Left threshold for control group, and RC= Right threshold for control group.

Figure 6 Estimated treatment effect, by group (average by perception gap)

5. Conclusions

In this study, we examine the features of expectation-updating behavior among survey respondents, based on an experiment that makes use of various information treatments. We aim to find clues as to how people process new information when updating expectations. We find this updating behavior to be quite heterogeneous among individuals. While our estimation results on information treatment are generally consistent with those seen in previous research, we did find additional features with respect to the formation of future expectations. Specifically, we find that responses to provided information are nonlinear. We presume that there exist certain intervals of revisions around zero, at which point people do not use provided information for updates; we find that this view is consistent with our survey results, which include a certain number of people who do not react to new information. What is more, respondents without any information treatment can be responsive to the provided "words": people are responsive to specific words, including "the BOJ" and "the price increase of ice cream products."

It would be encouraging for policymakers to find that information treatments are in general effective for consumers. In particular, people seem to have trust in future inflation developments as put forward by the BOJ, and seem to refer to that information when forming their expectations. However, we find that people's expectations can also be responsive to the information regarding future price changes among specific food items, even when the share of these items in their consumption basket is quite small. This implies the possibility that people's expectations can be volatile in response to news of price changes among various items in their basket. At the same time, we note that the inflation expectations of consumers can be influenced by keywords that do not contain any specific information; this finding implies that the mechanism of information-processing differs from the usual learning model seen in the literature, although detailed evidence is needed before we can examine the mechanism further.

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Appendix

The basic structure of the experiment consists of the following three stages.

1. Eliciting inflation expectations from each subject (first question on inflation expectations)

2. Eliciting the prior perceptions of the information related to future inflation developments (subjective priors)

Respondents in each Group are asked a question about either the inflation outlooks of professional institutions or scheduled price changes of particular grocery items as below.

a. Group 1 (Government outlook group): In the "government outlook group," respondents are asked: "The Japanese government publishes around January each year the inflation outlook for the upcoming fiscal year. How high do you think the most recent rate of expected inflation by the Japanese government is?"

b. Group 2 (Private outlook group): In the "professional-forecasters outlook group," respondents are asked: "A group of professional economists in the private sector regularly reports its expectations of future inflation. How high do you think the most recent rate of expected inflation by the professional economists is?"

c. Group 3 (BOJ outlook group): In the "BOJ group," respondents are asked: "The members of the Policy Board of the Bank of Japan predict future inflation on a regular basis. How high do you think the most recent rate of expected inflation by the BOJ is?"

d. Group 4 (Noodle group): For the "noodle group," the survey explains: "Major producers of instant noodles announced this month increases in the price levels of their products, because of an increase in the costs of transportation, raw materials, or personnel expenses." Then respondents are asked: "What do you think will be the extent of such price changes, in percentage points?"

e. Group 5 (Frozen meal group): For the "frozen meal group," the survey explains: "Major producers of frozen meals announced this month planned increases in the price levels of their household products, because of an increase in the costs of transportation, raw materials, or personnel expenses." Then respondents are asked: "What do you think will be the extent of such price changes, in percentage points?"

f. Group 6 (Ice cream group): For the "ice cream group," the survey explains: "Major confectionery companies announced planned increases in the price levels of some of their ice cream products, because of an increase in the costs of raw materials, or wrapping." Then, the respondents are asked: "What do you think is the extent of such price changes, in percentage points?"

3-1. Providing subjects in the treatment group with true measures of the aforementioned information would constitute a signal to the subject in the formation of expectations; in the case of the control group, the subject receives no signal (information treatment)

3-2. Eliciting inflation expectations from each subject again (second question on inflation expectations)

Only respondents in the treatment groups are provided with the correct answer to the question posed in the previous stage as follows.

a. **Group 1:** "According to the government outlook published this month, the government forecasts a CPI inflation rate of **1.4%** over 2015FY."

b. **Group 2:** "According to the outlook by professional forecasters in the private sector, they expect the future inflation rate over the next fiscal year (2015FY) to be **0.2–1.8%**, with a mean value of **0.84%**."

c. **Group 3:** "According to the outlook of the policy board members of the BOJ, they expect the future inflation rate over the next fiscal year (2015FY) to be **0.4–1.3%**, with a median value of **1.0%**."

d. **Group 4:** "According to the news release, several large food manufacturers that produce instant noodles intend to increase their product prices by **5–8%** this January. In addition, major noodle companies announced that they intend to increase the prices of chilled noodles by **4–9%** next March."

e. **Group 5:** "According to the news release, several large food manufacturers announced that they intend to increase the prices of frozen meals for households by **3–10%** next February."

f. **Group 6:** "According to the news release, several large confectionary manufacturers announced that they intend to increase the prices of some ice cream products by **8–10%** next March."