Households' Liquidity Constraint, Optimal Attention Allocation, and Inflation Expectations*

Hibiki Ichiue† Bank of Japan
Maiko Koga‡ Bank of Japan
Tatsushi Okuda§ Bank of Japan
Tatsuya Ozaki¶ Bank of Japan

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Abstract

We theoretically and empirically investigate the implications of heterogeneity in households' inflation expectations formation within an economy. We develop a rational inattention model in which households attempt to minimize the expected loss from insufficient bargain-hunting and inefficient inter-temporal consumption allocation. The model focuses on households' allocation of attention to two variables: the cheapest price of a particular product they can find, and the inflation rate the central bank aims to achieve in the long run. The model yields the clear prediction that households with a tighter liquidity constraint will allocate more attention to finding the cheapest price of a good by visiting different stores and less attention to information on the inflation rate the central bank aims to achieve in the long run including messages sent out by the central bank. Using a unique and rich micro dataset of Japanese households, we find empirical support for the testable prediction of our model. The model provides the important policy implication that households pay more attention to messages emitted by the central bank if monetary easing successfully relieves households' liquidity constraints.

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†Research and Statistics Department, Bank of Japan: hibiki.ichiue@boj.or.jp
‡Research and Statistics Department, Bank of Japan: maiko.koga@boj.or.jp
§Research and Statistics Department, Bank of Japan: tatsushi.okuda@boj.or.jp
¶Research and Statistics Department, Bank of Japan: tatsuya.ozaki@boj.or.jp

1 Introduction

The anchoring of long-run inflation expectations has received considerable attention in the macroeconomics literature. In particular, with the effective lower bound on nominal interest rates becoming binding, the anchoring of inflation expectations has taken on a new role as a potential instrument of monetary policy (Reifschneider and Williams 2000; Eggertsson and Woodford 2003). Central banks facing the lower bound on nominal interest rates have adopted the strategy of actively trying to raise inflation expectations to reduce real interest rates and stimulate economic activity.

Against this background, various studies have investigated the formation of economic agents' inflation expectations. For instance, Coibion and Gorodnichenko (2015) propose a framework to examine the degree of information rigidity in agents' expectations formation process and show that the expectations formation process of professional forecasters is consistent with imperfect information models. Similarly, Kumar et al. (2015) and Coibion, Gorodnichenko, and Kumar (2018) empirically examine the expectations formation process of firms and show that they follow a rational inattention mechanism. Coibion et al. (2018) even investigate the formation process of firms' expectations of rival firms' expectations.

In terms of the expectations formation process of households, Cavallo, Cruces, and Perez-Truglia (2017) compare the updating process of households' inflation expectations in the United States and Argentina to show that households' expectations formation is partially consistent with rational inattention models.[1] However, little is known about the implications of heterogeneity in households' inflation expectations formation within an economy.

Against this background, this paper proposes a structural framework for modeling households' heterogeneous inflation expectations formation by explicitly incorporating heterogeneity in households' economic situation and their attention allocation problem. Under the framework, we find a theoretical link between heterogeneity in the degree of liquidity constraints across households and their inflation expectations formation. Using a unique and rich micro dataset of Japanese households, we empirically confirm the link.

We develop a rational inattention model in which households attempt to minimize the

[1] Cavallo, Cruces, and Perez-Truglia (2017) present evidence from a survey experiment in which they give treatment groups a range of information related to inflation, such as inflation statistics or price changes for specific products. They conclude that individuals in a lower-inflation country such as the United States have significantly weaker priors about inflation rates, while those in a higher-inflation country such as Argentina have stronger priors.

expected loss from insufficient bargain-hunting and inefficient inter-temporal consumption allocation. The model focuses on households' allocation of attention to two variables: the cheapest price of a particular product they can find, and the aggregate inflation rate that the central bank aims to achieve in the long run. The model yields two testable predictions: (i) the inflation expectations of households with a tighter liquidity constraint correlate more closely with their own inflation experience (i.e., their inflation perceptions), and (ii) such households are also less attentive to information about the central bank's inflation target. We then empirically test the model by examining these predictions using the micro dataset on Japanese households. The dataset consists of survey results on households' inflation perceptions and inflation expectations, together with information on households' demographic characteristics. Finding that our model is confirmed by the data, we draw an important policy conclusion from the exercise: alleviation of households' liquidity constraint influences their optimal attention allocation and ultimately increases the effectiveness of the central bank's communication of its inflation target.

Framework. In the model, households, which are assumed to have limited information capacity and be liquidity constrained, attempt to minimize the expected loss from insufficient bargain-hunting and inefficient inter-temporal consumption allocation by allocating their attention to information about the two variables mentioned earlier, i.e., the cheapest price of a particular product they can find, and the central bank's long-run inflation target. The model assumes that the larger the number of prices households observe by visiting different stores, the lower are the prices they pay on average, and the more precise are their perceptions of current inflation. Moreover, the more attention households pay to messages sent out by the central bank, the more accurate is their understanding of the inflation rate that the central bank aims to achieve in the long run. The model further assumes that the future inflation rate depends on both the current inflation rate and the central bank's inflation target. In other words, inflation exhibits a certain degree of persistence and is partly controlled by the central bank. Our focus is on how households' liquidity constraints influence their optimal attention allocation and consequently their formation of inflation expectations.

Main predictions. The model yields a clear prediction: households with a tighter liquidity constraint will allocate more attention to finding the cheapest price of a good by visiting different stores and less attention to information on the inflation rate the central bank aims

to achieve in the long run, including messages sent out by the central bank. A tighter liquidity constraint restricts households' ability to change their inter-temporal allocation of consumption and therefore reduces their incentive to form precise inflation expectations, which are useful for forming precise expectations of the real interest rate. Hence, households with less interest in future inflation pay more attention to the distribution of prices in the current period and less attention to information on the inflation rate the central bank aims to achieve in the long run.

The model also establishes two testable predictions. First, the inflation expectations of households with a tighter liquidity constraint will be more closely correlated with their own inflation perceptions. Households with a tighter liquidity constraint and thus with less interest in future inflation spend more time bargain-hunting. As a result, the averages of the prices such households observe in stores—that is, their inflation perceptions—become more precise signals of the current aggregate inflation rate, and such households' inflation expectations are likely to be updated in response to inflation perceptions. Given that future inflation depends on current aggregate inflation, the inflation perceptions of households with a tighter liquidity constraint have a stronger influence on their inflation expectations than is the case for households with a looser liquidity constraint. The second prediction of the model is that households with a tighter liquidity constraint know less about the inflation target or the policy of the central bank.

Empirical results. Using the micro dataset of Japanese households, we find empirical support for the testable predictions of our model. The micro dataset we use for our analysis is constructed primarily from the following two sources: the household survey data of the "Opinion Survey on the General Public's Views and Behavior" compiled by the Bank of Japan, and the microdata of the "Preference Parameters Study" conducted by Institute of Social and Economic Research at Osaka University. The datasets are unique and rich in that they include information on households' inflation expectations as well as their demographic characteristics.

Using these datasets, we first conduct a preliminary analysis and then examine the two testable predictions of our model. The preliminary analysis shows that while households do incorporate changes in their inflation expectations into their inter-temporal allocation of consumption, lower-income households' consumption is relatively insensitive to changes in their inflation expectations. This finding implies that lower-income households face a tighter

liquidity constraint and we therefore use lower-income households as a proxy for households with a tighter liquidity constraint. Consistent with our theoretical considerations, we find that the inflation expectations of lower-income households (i.e., households with a tighter liquidity constraint) are more sensitive to changes in their inflation perceptions and that such households know less about the inflation target or the policy of the central bank.

Main policy implication. The results of our analysis provide policy implications regarding measures to anchor households' inflation expectations. Importantly, by alleviating households' liquidity constraints, monetary easing ultimately has the potential to enhance households' attention to the messages sent out by the central bank. That is, if monetary easing successfully relieves households' liquidity constraints, households can more flexibly adjust their inter-temporal allocation of consumption in response to changes in their inflation expectations. Under such circumstances, households are more attentive to information on future inflation including the central bank's inflation target and start to listen to the central bank's messages.[2]

Related literature. Our study is closely related to two strands of literature.

First, our study is linked to the literature on the formation process of households' inflation expectations at the micro-level using imperfect information models.[3] Some studies explore how agents process their information with exogenously determined information structures. For example, Carroll (2003) and Pfajfar and Santoro (2013) examine the connection between households' inflation forecasts and information including professional forecasts and media news. Coibion and Gorodnichenko (2012) and Abe and Ueno (2018), focusing respectively on the United States and Japan, report that households' inflation expectations are consistent with Bayesian updating. More recent works suggest that households acquire information by choice. Examining the relationship between aggregate inflation volatility and households' inflation expectations formation, Cavallo, Cruces, and Perez-Truglia (2017) and Dräger and Lamla (2017) provide results implying that households' behavior follows the

[2] An interesting study in this context is that by Coibion, Gorodnichenko, and Weber (2019), who empirically examine the effectiveness of different forms of central bank communication.

[3] Apart from imperfect information, the literature has explored a range of other determinants of households' inflation expectations. For instance, Souleles (2004) shows that households' inflation expectations are correlated with their income. Blanchflower and MacCoille (2009) demonstrate that inflation expectations are associated with age, education, and home ownership. Malmendier and Nagel (2016) and Diamond, Watanabe, and Watanabe (2018) argue that cohort effects play a key role in households' expectations formation.

rational inattention hypothesis. However, neither of them investigate the implications of households' heterogeneous inflation expectations formation within the economy. Our study contributes to the literature both from a theoretical and an empirical perspective by proposing a theoretical framework to account for heterogeneity in households' inflation expectations formation within the economy and providing empirical evidence that is consistent with our theoretical framework.

Second, our study is also related to the theoretical literature on households' attention allocation.[4] Sims (2003, 2005, 2006), Luo (2008), and Tutino (2013) construct models of households' attention problem considering mainly the effects of imprecision in households' perceptions of variables on inter-temporal consumption smoothing and wage setting. Our study follows a similar vein, but our main focus is on households' inflation expectations, and we examine households' incentives with regard to the allocate of attention to two types of price information, namely, the price distribution of the homogeneous good in the current period and information on future changes in aggregate prices.

Outline. The remainder of the paper is organized as follows. Section 2 develops the model of households' attention allocation problem, while Section 3 presents the two theoretical predictions derived from the model. Section 4 then empirically tests the predictions using the micro dataset on Japanese households. Finally, Section 5 discusses the policy implications, while Section 6 concludes. The Appendices contain the proofs and empirical robustness checks.

2 Framework: Attention Allocation

Environment. The economy is populated by a representative household and an infinite number of stores ($i \in [0, 1]$). The household faces information constraints and liquidity constraints and allocates attention to the distribution of prices in the current period and the future average price in order to minimize the expected loss from insufficient bargain-hunting and inefficient inter-temporal consumption allocation.[5]

[4] For studies on firms' attention allocation problem, see Maćkowiak and Wiederholt (2009) and Paciello (2012). Meanwhile, Maćkowiak and Wiederholt (2015) analyze the attention allocation problem of both households and firms in a general equilibrium setting.

[5] Several papers including Guimaraes and Sheedy (2011) and Sudo et al. (2018) develop macroeconomic models that incorporate bargain-hunting by households.

That is, to maximize utility, the household tries to find the cheapest price of a good by visiting different stores and, moreover, aims to purchase the good in a period when the price of the good is low. Because our interest is in the household's attention allocation problem, inflation dynamics and the households' income process are taken as given. We assume that goods are homogeneous and that the price dispersion of a particular good across stores is determined by idiosyncratic stochastic factors in the first period ($t = 0$) that fully persist in the second period ($t = 1$).[6] For the sake of analytical simplicity, we assume that in the second period ($t = 1$) the household needs to purchase the good at the same store as in the first period ($t = 0$).

The model then examines the household's optimal attention allocation to information about two variables: the cheapest price of a particular good in the current period and the aggregate inflation rate the central bank aims to achieve in the long run. While we recognize that the model is highly stylized in order to be tractable, the analytical results on households' attention allocation problem and the formation of inflation expectations should still hold in a more general setting. The details of the settings of our model are as follows.

Setup. The representative household, which purchases and consumes the homogeneous good, has the following utility function:

$$\mathbb{EU} = \ln C_0 + \beta \mathbb{E}_0 \left[\ln C_1 \right],$$

where C_t denotes the household's consumption in period $t \in \{0, 1\}$, and β is the subjective time discount factor. $\mathbb{E}_0$ is the expectations operator conditional on the household's information set in period 0 after its decision on attention allocation (which is specified later).

The budget constraint of the household is given by

$$\begin{aligned} C_0 \chi_0 + S_0 &= I_0, \\ \chi_1 C_1 &= I_1 + R_1 S_0, \end{aligned}$$

where I_t denotes the household's deterministic real income (endowment) in period $t \in \{0, 1\}$, S_0 represents the household's saving in period 1, R_1 is the gross real interest rate, and χ_t captures the lack of intensity or effectiveness of the household's price search and thus represents

[6] The assumption that the law of one price is violated is underpinned by the empirical findings of various studies such as Stigler (1961) and Sorensen (2000). Moreover, in a recent study, Kaplan and Menzio (2015) found that the price distributions for identical goods in a given time period are highly dispersed.

the degree of imperfection of the household's knowledge regarding the price distribution of the homogeneous good. We specify the function of χ_0 as follows:[7]

$$\chi_0 \equiv \exp\left(\Gamma\left(\frac{1}{n}\sum\nolimits_{i=1}^{n}\ln\left(P_0(i)/P_0\right)\right)^2\right) \in [1,\infty),$$

where $P_0(i)$ is the price at store $i \in [0,1]$ in period 0, P_0 is the aggregate price ($\ln P_0 \equiv \int_{i\in[0,1]} \ln P_0(i)$) in period 0, and $\Gamma > 0$ is a constant. The search intensity is represented by n, which is the number of stores the household visits. As will be specified later, the prices across stores are log-normally distributed. The greater the price search intensity (n), the smaller χ_0 becomes, converging to one following the central limit theorem. Intuitively, the specification of χ_0 represents the relationship that the household can find a cheaper price ($\chi_0 \downarrow$) by visiting a larger number of stores ($n \uparrow$).[8] Because it is assumed that in the second period ($t = 1$) the household purchases the good at the same store as in the first period ($t = 0$), $\chi_1 = \chi_0$ holds.

The real interest rate R_1 is composed of the nominal interest rate and the gross inflation rate ($\Pi_1 \equiv P_1/P_0$) in line with the Fisher equation. For the sake of simplicity, we assume $\beta = 1$ and thus $R_{ss} = \beta^{-1} = 1$ and $I = I_0 = I_1$. Note that R_{ss} is the real interest rate in a steady state where no shock occurs and every variable is deterministic.

The household's liquidity constraint is represented by $\theta \in [0,1]$ and specified as follows:

$$-\theta I_1 R_{ss}^{-1} = -\theta I \leq S_0.$$

The household can borrow at most θ of the (*ex ante*) present value of its expected future income ($I_1 R_{ss}^{-1}$).

In the following, we first derive the optimal consumption allocation by taking the exogenously determined information structure as given and characterize the expected loss of utility from the optimal consumption allocation. The expected loss of utility is measured as the difference between the level of utility when consumption is determined in a perfect information environment and the level of utility when consumption is determined under an imperfect information environment. We then identify the optimal attention allocation as the allocation that achieves the lowest expected loss under the household's limited information capacity.

[7] We view this specification as an approximation of $\chi_0 = min\{P_0(1), P_0(2), ..., P_0(n)\}$, because χ_0 is monotonically decreasing in n in both specifications.

[8] The assumption that greater search intensity results in lower prices paid follows Lee, Luengo-Prado, and Sorensen (2018). The assumption is also supported by the empirical findings of Kaplan and Menzio (2015).

Optimal consumption. We denote the log deviation from steady state values by small letters; i.e., $c_t \equiv \ln(C_t/C_{ss})$ and $x_t = \ln(\chi_t/\chi_{ss})$. Again, the real interest rate $\mathbb{E}_0[r_1] \equiv \mathbb{E}_0[\ln(R_1/R_{ss})]$is composed of the nominal interest rate and inflation expectations $\mathbb{E}_0[\pi_1] \equiv \mathbb{E}_0[\ln \Pi_1] = \mathbb{E}_0[\ln(P_1/P_0)]$. Because inflation expectations play a crucial role in economic fluctuations, particularly when the zero lower bound on interest rates is binding (e.g., Kumar et al. 2015), we assume that the nominal interest rate is binding at zero.

Then the optimal consumption allocation under the exogenously determined information structure, $(c_0^*, \mathbb{E}_0[c_1^*])$, is defined as the consumption allocation $(c_0, \mathbb{E}_0[c_1])$that maximizes the household's expected utility $\mathbb{EU}$ with the budget constraint, liquidity constraint, and exogenously given $\chi_0(=\chi_1)$and $\mathbb{E}_0[\pi_1]$. The optimal consumotion allocation is then determined as follows.

Lemma 1 *For any exogenously determined information structures* $(\chi_0, \mathbb{E}_0[\pi_1])$*, the optimal consumption allocation* $(c_0^*, \mathbb{E}_0[c_1^*])$ *is given as follows:*

$$c_0^* = \min\left\{\frac{1}{2}\mathbb{E}_0[\pi_1], \theta\right\} - x_0, \tag{1}$$

$$\mathbb{E}_0[c_1^*] = \max\left\{-\frac{1}{2}\mathbb{E}_0[\pi_1], -\theta\right\} - x_0. \tag{2}$$

Proof: See Appendix A.1. □

This lemma shows that c_0^* is increasing in $\mathbb{E}_0[\pi_1]$ and $\mathbb{E}_0[c_1^*]$ is decreasing in $\mathbb{E}_0[\pi_1]$; that is, a lower real interest rate $\mathbb{E}_0[i - \pi_1] = \mathbb{E}_0[-\pi_1]$ boosts current consumption. There are two differences in our model specification from canonical consumption models. First, c_0^* and $\mathbb{E}_0[c_1^*]$ are decreasing in x_0. This follows from the relationship that a greater price search intensity ($x_0 \downarrow$) allows the household to find a cheaper price and increase its consumption. Second, there exists an upper bound for c_0^* (θ) and a lower bound for $\mathbb{E}_0[c_1^*]$ $(-\theta)$, i.e., due to the liquidity constraint, the household cannot fully adjust consumption by raising the ratio of current consumption to future consumption. Note that under the liquidity constraint the sensitivity of consumption $(c_0^*, \mathbb{E}_0[c_1^*])$ to changes in inflation expectations $\mathbb{E}_0[\pi_1]$ exhibits a kink, as shown in the following expression:

$$\frac{\partial c_0^*}{\partial \mathbb{E}_0[\pi_1]} = -\frac{\partial \mathbb{E}_0[c_1^*]}{\partial \mathbb{E}_0[\pi_1]} = \begin{cases} \frac{1}{2} \text{ for } \frac{1}{2}\mathbb{E}_0[\pi_1] \leq \theta \\ 0 \text{ for } \frac{1}{2}\mathbb{E}_0[\pi_1] > \theta \end{cases}.$$

The expression indicates that a tighter liquidity constraint (lower θ) means that the household adjusts its consumptions $(c_0^*, \mathbb{E}_0[c_1^*])$ in accordance with changes in inflation expectations $\mathbb{E}_0[\pi_1]$ to a lesser extent.

Expected loss function. We next characterize the expected loss from limited information as the difference from the level of utility when consumption is determined in a perfect information environment:

$$c_0^{**} = \ln C_0^{**} = \min\left\{\frac{1}{2}\pi_1, \theta\right\}, \tag{3}$$

$$c_1^{**} = \ln C_1^{**} = \max\left\{-\frac{1}{2}\pi_1, -\theta\right\}, \tag{4}$$

Note that when the household has perfect information in the first period, the inflation rate in the second period is deterministic, since we assume that there are no shocks in the second period.

We define the deviation of consumption under imperfect information from that under perfect information as $\widehat{c}_t \equiv \ln\left(C_t^*/C_t^{**}\right) = c_t^* - c_t^{**}$.

Lemma 2 *Using Lemma 1, the second-order approximation of the expected loss around* (C_0^{**}, C_1^{**}) *is given as follows:*

$$\mathbb{EL} \approx -\mathbb{E}\left[\widehat{c}_0 + \widehat{c}_1 - \frac{1}{2}\left(\widehat{c}_0\right)^2 - \frac{1}{2}\left(\widehat{c}_1\right)^2\right] \tag{5}$$

$$= \mathbb{E}\left[2x_0 + x_0^2\right] + \mathbb{E}\left[\left(\min\left\{\frac{1}{2}\mathbb{E}_0\left[\pi_1\right], \theta\right\} - \min\left\{\frac{1}{2}\pi_1, \theta\right\}\right)^2\right]. \tag{6}$$

Proof: See Appendix A.2. □

Equation (5) indicates that as the amount of consumption becomes larger and the deviation of consumption due to imperfect information decreases, the expected loss becomes smaller. By substituting conditions (1), (2), (3) and (4) into (5), we obtain equation (6). This shows that the sources of the expected loss are twofold. First, insufficient bargain-hunting ($x_0 > 0$) causes expected losses. Note that an increase in x_0 leads to a larger expected loss, and if the household knows all of the prices in the economy by visiting all stores ($n_0 \to \infty$ and $x_0 \to 0$), then the expected loss from $\mathbb{E}\left[2x_0 + x_0^2\right]$ becomes zero. Second, inefficient inter-temporal consumption allocation caused by forecast errors about the future inflation rate also generates expected losses, which, however, are bounded above, with the bound depending on the liquidity constraint ($\theta \in [0, 1]$).[9] Note that the expected loss from $\mathbb{E}\left[\left(\min\left\{\frac{1}{2}\mathbb{E}_0\left[\pi_1\right], \theta\right\} - \min\left\{\frac{1}{2}\pi_1, \theta\right\}\right)^2\right]$ becomes zero if $\mathbb{E}_0\left[\pi_1\right] = \pi_1$ always holds; that is, the household forms perfectly accurate inflation expectations.

[9] Maćkowiak and Wiederholt (2012, 2018) analyse a similar problem. Specifically, they examine firms' attention allocation when the expected losses are bounded above due to the limited liability constraint.

Because the non-linearity of the second term is intractable, we approximate the second term as follows:

$$\mathbb{E}\left[\left(\min\left\{\mathbb{E}_0\left[\pi_1\right]/2,\theta\right\}-\min\left\{\pi_1/2,\theta\right\}\right)^2\right]\approx(1+\theta)\,\mathbb{E}\left[\left(\mathbb{E}_0\left[\pi_1\right]-\pi_1\right)^2\right]/8.$$

The process of and justification for the approximation are shown in Appendix A.3. This approximation can be interpreted as follows. The household's expected loss decreases monotonically as the household's inflation expectations become more precise in particular when its liquidity constraint becomes tighter. This is because, as the liquidity constraint becomes tighter ($\theta\downarrow$), the household's ability to change its inter-temporal allocation of consumption is more restricted. In an extreme case, if the liquidity constraint is very tight ($\theta\to 0$), then the household cannot increase the ratio of current to future consumption. Therefore, the expected loss for the household occurs only if $\mathbb{E}_0\left[\pi_1\right]<0$ holds, that is, only if the household thinks it should postpone some part of its current consumption.

Under this approximation, the expected loss (6) for the household is expressed as follows:

$$\mathbb{E}\left[2\Gamma\left(\frac{1}{n}\sum\nolimits_{i=1}^{n}p_0(i)-p_0\right)^2+\Gamma^2\left(\frac{1}{n}\sum\nolimits_{i=1}^{n}p_0(i)-p_0\right)^4+\frac{1+\theta}{8}\left(\mathbb{E}_0\left[\pi_1\right]-\pi_1\right)^2\right],$$

where $2\Gamma\left(\frac{1}{n}\sum_{i=1}^{n}p_0(i)-p_0\right)^2+\Gamma^2\left(\frac{1}{n}\sum_{i=1}^{n}p_0(i)-p_0\right)^4$ captures the loss from insufficient bargain-hunting, while $(1+\theta)\left(\mathbb{E}_0\left[\pi_1\right]-\pi_1\right)^2/8$ represents the loss from inefficient inter-temporal consumption allocation.

Inflation dynamics. For the household, aggregate inflation dynamics (π_0,π_1) and store-level prices $(p_0(i))$ are exogenously determined as follows:[10]

$$\pi_0 = (1-\rho)\,\pi^*+\epsilon_0, \tag{7}$$

$$\pi_1 = \rho\pi_0+(1-\rho)\,\pi^*, \tag{8}$$

$$p_t(i) = p_t+x(i) \tag{9}$$

The assumptions on inflation dynamics are as follows. In terms of aggregate inflation dynamics (7) and (8), the dynamics exhibit some degree of persistence $\rho\in(0,1)$ and are only partly anchored to $\pi^*\sim\mathcal{N}(0,\sigma^2_{\pi^*})$, that is, the inflation rate the central bank aims to achieve in the long run. We can interpret π^* as the inflation target set by the bank or

[10] This setup is similar to the household's perceived law of motion for inflation in Vellekoop and Wiederholt (2019).

trend inflation. In period $t = 0$, aggregate inflation is subject to innovation $\epsilon_0 \sim \mathcal{N}(0, \sigma_\epsilon^2)$. Store-level prices (9) are subject to store-level idiosyncratic price shocks in period $t = 0$, $x(i) \sim \mathcal{N}(0, \sigma_x^2)$. We normalize the log of the aggregate price and the inflation rate in the previous period to zero. Therefore, the identities $p_0 = \pi_0$ and $p_1 = p_0 + \pi_1$ hold. We define $\widetilde{\pi}_0 \equiv \frac{1}{n}\sum_{i=1}^{n} p_0(i) \sim \mathcal{N}(\pi_0, \frac{1}{n}\sigma_x^2)$ and $\sigma_{x|s}^2 \equiv \frac{1}{n}\sigma_x^2$. We refer to $\widetilde{\pi}_0$ as inflation perceptions

Information constraint. The household faces the following information constraint:

$$\frac{1}{2}\log_2\left(\frac{\sigma_{x|s}^{-2}}{\sigma_x^{-2}}\right) + \Omega\frac{1}{2}\log_2\left(\frac{\sigma_{\pi^*|s}^{-2}}{\sigma_{\pi^*}^{-2}}\right) \leq \kappa,$$

where κ is the upper limit for information processing, that is, the household's information processing capacity, and Ω is the relative information processing cost for one unit of Shannon entropy normalized by the cost of price search. σ_x^{-2} and $\sigma_{\pi^*}^{-2}$ represent the precision of priors on the price distribution and the inflation target, while $\sigma_{x|s}^{-2}$ $(\succeq \sigma_x^{-2})$ and $\sigma_{\pi^*|s}^{-2}$ $\left(\succeq \sigma_{\pi^*}^{-2}\right)$ represent the precision of the corresponding posteriors. If the household obtains more precise information about the cheapest price available, $(\sigma_{x|s}^{-2})$, the term $\frac{1}{2}\log_2\left(\frac{\sigma_{x|s}^{-2}}{\sigma_x^{-2}}\right)$ on the left-hand side of the inequality increases. On the other hand, if the household obtains more precise information about the target inflation rate $(\sigma_{\pi^*|s}^{-2})$, the term $\Omega\frac{1}{2}\log_2\left(\frac{\sigma_{\pi^*|s}^{-2}}{\sigma_{\pi^*}^{-2}}\right)$ on the left-hand side increases. Because the right hand side, κ, is finite, and $\frac{1}{2}\log_2\left(\frac{\sigma_{x|s}^{-2}}{\sigma_x^{-2}}\right) + \Omega\frac{1}{2}\log_2\left(\frac{\sigma_{\pi^*|s}^{-2}}{\sigma_{\pi^*}^{-2}}\right)$ goes to infinity if the household holds perfect information about either or both variables $(\sigma_{x|s}^{-2} \to \infty$ and/or $\sigma_{\pi^*|s}^{-2} \to \infty)$, this inequality indicates that (i) the household's expectations are always noisy due to the information constraint, and (ii) it also faces a trade-off in that obtaining more precise information about the cheapest price available (a larger $\sigma_{x|s}^{-2}$) leads to less precise information about the inflation rate the central bank aims to achieve in the long run (a larger $\sigma_{\pi^*|s}^{-2}$), and vice versa.

The household minimizes the expected loss taking inflation dynamics and the information constraint into account, as will be shown in the next section.

3 Main Results

This section solves the household's attention allocation problem and conducts a comparative static analysis of the household's optimal attention allocation $\left(\sigma_{x|s}^{-2}\right)^*$ and $\left(\sigma_{\pi^*|s}^{-2}\right)^*$ with respect to changes in θ. In addition, it also examines the effects of changes in θ on the relationship between inflation perceptions and inflation expectations.

3.1 Optimal Attention Allocation

Under the setting above, we obtain the following results.

Proposition 1 *(i) The precision of the posteriors* $\left(\left(\sigma_{x|s}^{-2}\right)^*, \left(\sigma_{\pi^*|s}^{-2}\right)^*\right)$ *solves the household's attention problem, which is as follows:*

$$\min_{\left(\sigma_{x|s}^{-2}, \sigma_{\pi^*|s}^{-2}\right)} \left[2\Gamma\sigma_{x|s}^2 + 3\Gamma^2 \left(\sigma_{x|s}^2\right)^2 + \frac{1+\theta}{8} \left(\begin{array}{c} \rho^2\lambda^2\sigma_{x|s}^2 + (1-\rho)^2 \left[1+\rho\left(1-\lambda\right)\right]^2 \sigma_{\pi^*|s}^2 \\ +\rho^2 \left(1-\lambda\right)^2 \sigma_\epsilon^2 \end{array} \right) \right], \tag{10}$$

where $\lambda \equiv \sigma_{x|s}^{-2} / \left(\sigma_{x|s}^{-2} + \left[(1-\rho)^2 \sigma_{\pi^*|s}^2 + \sigma_\epsilon^2 \right]^{-1} \right)$, *and*

$$\sigma_{\pi^*|s}^{-2} = \sigma_{\pi^*}^{-2} \left(\frac{\sigma_x^{-2}}{\sigma_{x|s}^{-2}} 2^{2\kappa} \right)^{\frac{1}{\Omega}}, \sigma_{x|s}^{-2} \succeq \sigma_x^{-2}, \sigma_{\pi^*|s}^{-2} \succeq \sigma_{\pi^*}^{-2}. \tag{11}$$

(ii) $\left(\sigma_{x|s}^{-2}\right)^*$ *is decreasing in* θ *and* $\left(\sigma_{\pi^*|s}^{-2}\right)^*$ *is increasing in* θ.

Proof: See Appendix A.4. □

The household's attention allocation problem is determined by the severity of the liquidity constraint θ (proposition 1 (i)). Specifically, the household's attention to current prices at stores increases and that to the inflation rate the central bank aims to achieve in the long run decreases as θ becomes lower, that is, as the liquidity constraint becomes tighter (proposition 1 (ii)).

A lower θ means the household faces a tighter liquidity constraint. The tighter constraint, in turn, means that inflation expectations become less relevant to the household's decision-making, since the household's ability to act on changes in inflation expectations by adjusting its inter-temporal allocation of consumption decreases. As a result, the household becomes less attentive to information that is useful for predicting future inflation.

We illustrate these properties through numerical exercises using the model.

Parameterization. For the exercises, we set $\sigma_\epsilon^2 = 4$, $\sigma_{\pi^*}^2 = 0.25$, $\sigma_x^2 = 1$, $\kappa = 1$, $\Gamma = 0.05$, $\Omega = 1$ and $\rho = 0.25$. We allow θ to vary from zero to one. We use this parameterization in the following exercises.

θ and $\left(\sigma_{x|s}^{-2}\right)^*, \left(\sigma_{\pi^*|s}^{-2}\right)^*$. Figure 1 plots the relationship between θ and the precision of information held by the household on the distribution of prices in the current period and

the inflation rate the central bank aims to achieve in the long run as a result of its optimal attention allocation. In the figure, the bold line, which represents the precision of information on the distribution of prices in the current period, $\left(\sigma_{x|s}^{-2}\right)^*$, decreases monotonically in θ while the dotted line, which represents the precision of information on the inflation rate the central bank aims to achieve in the long run, $\left(\sigma_{\pi^*|s}^{-2}\right)^*$, increases monotonically in θ. We interpret these results as follows: the less interest the household has in the inter-temporal allocation of consumption, the more attention it allocates to the distribution of prices in the current period than the inflation rate the central bank aims to achieve in the long run.

[Figure 1 about here]

3.2 Inflation Perceptions and Inflation Expectations

Next, given the endogenously determined information structures $\left(\left(\sigma_{x|s}^{-2}\right)^*, \left(\sigma_{\pi^*|s}^{-2}\right)^*\right)$, we derive the properties of inflation expectations. Taking the conditional expectations of the information set in period 0 with respect to equation (8), we obtain

$$\mathbb{E}_0\left[\pi_1\right] = \rho\mathbb{E}_0\left[\pi_0\right] + (1-\rho)\,\mathbb{E}_0\left[\pi^*\right]. \tag{12}$$

Next, as shown in the proof of proposition 1, because inflation perceptions $\widetilde{\pi}_0 \equiv \frac{1}{n}\sum_{i=1}^{n} p_0(i) \sim \mathcal{N}(\pi_0, \sigma_{x|s}^2)$ and the priors with information on π^* included in equation (7) ($(1-\rho)\mathbb{E}_0[\pi^*]$) are unbiased signals of π_0, the aggregate period 0 inflation perceptions of the household are given by

$$\mathbb{E}_0[\pi_0] = \lambda\widetilde{\pi}_0 + (1-\lambda)(1-\rho)\mathbb{E}_0[\pi^*].$$

By substituting this equation into equation (12), the structural form of the household's inflation expectations is given by

$$\mathbb{E}_0\left[\pi_1\right] = \rho\lambda\widetilde{\pi}_0 + (1-\rho)\left[1+\rho\left(1-\lambda\right)\right]\mathbb{E}_0\left[\pi^*\right].$$

This expression shows how the relationship between inflation expectations $\mathbb{E}_0\left[\pi_1\right]$ and inflation perceptions $\widetilde{\pi}_0$ is governed by $\rho\lambda$. However, because the variables $\widetilde{\pi}_0$ and $\mathbb{E}_0\left[\pi^*\right]$ are correlated and it is difficult to control for $\mathbb{E}_0\left[\pi^*\right]$ in the empirical analysis that follows, we also derive the relationship in a reduced form. We denote the parameter governing the relationship between inflation expectations $\mathbb{E}_0\left[\pi_1\right]$ and inflation perceptions $\widetilde{\pi}_0$ in the structural form and the reduced form respectively by $\alpha \equiv \rho\lambda$ and $\gamma \equiv \mathbb{C}\left[\mathbb{E}_0\left[\pi_1\right], \widetilde{\pi}_0\right] / \mathbb{V}\left[\widetilde{\pi}_0\right]$. The structural and reduced form parameters thus look as follows.

Proposition 2 *With parameters* $\left(\left(\sigma_{x|s}^{-2}\right)^*, \left(\sigma_{\pi^*|s}^{-2}\right)^*, \rho\right)$*, the parameters governing the relationship between the household's inflation expectations and its inflation perceptions* (α, γ) *are as follows:*

$$\begin{aligned}\alpha &= \rho\lambda, \\ \gamma &= \frac{(1+\rho)(1-\rho)^2\sigma_{\pi^*}^2 + \rho\lambda\sigma_\epsilon^2 + \rho\lambda\left(\sigma_{x|s}^2\right)^*}{(1-\rho)^2\sigma_{\pi^*}^2 + \sigma_\epsilon^2 + \left(\sigma_{x|s}^2\right)^*},\end{aligned}$$

where,

$$\lambda \equiv \frac{\left(\sigma_{x|s}^{-2}\right)^*}{\left(\sigma_{x|s}^{-2}\right)^* + \left[(1-\rho)^2\left(\sigma_{\pi^*|s}^2\right)^* + \sigma_\epsilon^2\right]^{-1}}.$$

Proof: See Appendix A.5. □

We next examine the properties of inflation expectations from the perspective of anchoring expectations by providing numerical illustrations of (α, γ). The parameterization is the same as in Figure 1, and we insert the optimal attention allocation into $\left(\sigma_{x|s}^{-2}, \sigma_{\pi^*|s}^{-2}\right)$.

θ and (α, γ). Figure 2 depicts the relationship between θ and how the inflation expectations comove with inflation perceptions using the two measures (α, γ). The first measure, α, represents the comovement in structural form and the second one, γ, shows the link in reduced form. Importantly, both measures decrease along with θ. The reason is that the tighter the liquidity constraint, the less interested is the household in future inflation and consequently allocates more attention to finding the lowest price rather than understanding the long-run inflation rate. Thus, when the liquidity constraint is tight, there is high comovement between the household's inflation perceptions and inflation expectations.

[Figure 2 about here]

3.3 Two Key Theoretical Predictions

The next section examines the validity of our model using the dataset on Japanese households containing information on the inflation perceptions and inflation expectations of individual households as well as information on their income information. Our testable theoretical predictions for the exercise are as follows:

1. The inflation expectations of households with a tighter liquidity constraint are more sensitive to changes in their inflation perceptions.

2. Such households are less attentive to information on the inflation rate the central bank aims to achieve in the long run.

4 Empirical Analysis

This section describes the two household survey datasets we use for our analysis and presents the empirical examination and its results.

4.1 Description of the Dataset

We utilize two datasets that are useful for testing our theoretical predictions. The "Opinion Survey on the General Public's Views and Behavior" allows us to examine the association between households' inflation expectations and current inflation perceptions predicted by our model. It also provides information on households' attention to the central bank. In addition, to test the inter-temporal Euler equation derived in the model, we utilize "Preference Parameters Study" which provides numerical information on households' forecasted inflation rate, change in expenditure, and change in income.

Opinion Survey on the General Public's Views and Behavior. As mentioned, the first source for our dataset is the microdata from the "Opinion Survey on the General Public's Views and Behavior" conducted by the Bank of Japan. The survey started to monitor households' view on the economic situation such as economic conditions, income, consumption, price changes, and expectations in 1993. It was conducted annually from 1993 to 1998, semi-annually from 1999 to 2003, and has been conducted quarterly since 2004.[11] The survey also covers households' perceptions of the Bank of Japan's policies and their confidence in the Bank. For each survey, 4,000 individuals aged 20 or over are chosen and the response rate is approximately 50 percent.

The advantage of the Opinion Survey is that it collects households' responses on both inflation expectations and current inflation perceptions in the form of a choice among five

[11] This paper uses the 49 waves of the survey conducted from September 2006 to September 2018, during which the Bank of Japan sent out and received the questionnaires by post. Before September 2006, the Bank of Japan collected the questionnaires by visiting respondents' home. Kamada, Nakajima, and Nishiguchi (2015) point out that survey responses differ depending on which method is used.

categories.[12] More specifically, it asks households three questions about inflation, namely, (1) about their perception of actual inflation over the past year; (2) about their inflation expectation over the coming one-year period, and (3) about their inflation expectation over the next five years.

Concretely, the questions on inflation perceptions and one-year-ahead inflation expectations are as follows:

- *How do you think prices have changed compared with one year ago?*

  (Note: Prices are defined as overall prices of goods and services you purchase.)

  (a) Have gone up significantly, (b) Have gone up slightly, (c) Have remained almost unchanged, (d) Have gone down slightly, (e) Have gone down significantly.

- *What is your outlook for prices one year from now?*

  (a) Will go up significantly, (b) Will go up slightly, (c) Will remain almost unchanged, (d) Will go down slightly, (e) Will go down significantly.

Further, the Opinion Survey also covers questions about households' attitudes toward the Bank of Japan and their literacy regarding the Bank. For example, the survey contains the following questions and possible answers:

- *How would you describe your level of interest in the Bank's activities?*

  (a) Interested, (b) Somewhat interested, (c) Difficult to say, (d) Not particularly interested, (e) Not interested.

- *Do you know that the Bank has been implementing aggressive monetary easing measures to achieve the price stability target of 2 percent?*

  (a) Know about it, (b) Have read or heard of it, but do not know much about it, (c) Have never heard of it.

The items we use in the survey and their summary statistics are described in Table 1(a).

[12] The Opinion Survey also asks household about their expected inflation rate in the form of an exact number. However, as pointed out by Kamada (2013), various distortions are observed: responses are likely to be (i) integers, (ii) zeros, and (iii) multiples of 5, but (iv) are less likely to be negative values. Consequently, in this study, we only focus on the qualitative answers in the survey.

Preference Parameters Study. The other data is the "Preference Parameters Study" conducted by the Institute of Social and Economic Research at Osaka University. The dataset is based on a longitudinal annual survey that is conducted from January to March each year. The first wave was conducted in 2003, and we use the waves from 2004 to 2013, since there was a hiatus in 2014-2015.[13] The response rate to each survey is more than 70 percent, and the data cover about 4,000 households on average each year. Survey households are chosen based on stratified two-stage random sampling using the "Basic Resident Registration" compiled by the Ministry of Internal Affairs and Communications.

The advantage of this survey is that households are asked to choose items representing numerical ranges for the inflation rate they expect, the change in their expenditure, and the change in their income. For instance, in the case of inflation expectations, respondents are provided with one percentage point intervals, which means that their responses provide detailed information akin to quantitative data. The survey also provides information on households' consumption, financial situation, and demographic characteristics (gender, age, employment status, education etc.).

In the question on inflation expectations, households are required to choose one among eleven categories. Specifically, the question on inflation expectations looks as follows:

- *By what percentage do you expect consumer prices will change in 2013, compared with the previous year?*

  00. Decrease by at least 4.5%; 01. Decrease by at least 3.5% but less than 4.5%; 02. Decrease by at least 2.5% but less than 3.5%; 03. Decrease by at least 1.5% but less than 2.5%; 04. Decease by at least 0.5% but less than 1.5%; 05. Change by less than 0.5% in either direction; 06. Increase by at least 0.5% but less than 1.5%; 07. Increase by at least 1.5% but less than 2.5%; 08. Increase by at least 2.5% but less than 3.5%; 09. Increase by at least 3.5% but less than 4.5%; 10. Increase by at least 4.5%.

  Similarly, the question and possible answers regarding the expected change in expenditure look as follows:

- *In 2013 what will be the approximate percentage change in your family's total annual expenditures compared with 2012?*

[13] The survey started collecting responses on inflation expectations in 2004.

00. Decrease by at least 9%; 01. Decrease by at least 7% but less than 9%; 02. Decrease by at least 5% but less than 7%; 03. Decrease by at least 3% but less than 5%; 04. Decease by at least 1% but less than 3%; 05. Change by less than 1% in either direction; 06. Increase by at least 1% but less than 3%; 07. Increase by at least 3% but less than 5%; 08. Increase by at least 5% but less than 7%; 09. Increase by at least 7% but less than 9%; 10. Increase by at least 9%.

The items we use in the survey and their summary statistics are described in Table 1(b).

4.2 Preliminary Analysis: Income Level and Liquidity Constraint

In our theoretical framework, we derive that when the household is more liquidity constrained it can adjust its consumption in response to a change in inflation expectations to a lesser extent. This subsection examines this prediction by checking if households' liquidity constraint influences the link between their inflation expectations and consumption. Generally speaking, a higher expected rate of inflation lowers real interest rates, creating an incentive to spend now rather than in the future, provided that nominal interest rates are fixed. When households cannot adjust their consumption because they are liquidity constrained, the effect of inflation expectations on consumption diminishes. A number of studies have examined whether this relationship holds in practice and have found evidence in support (Ichiue and Nishiguchi 2014, D'Acunto, Hoang, and Weber 2016, Duca, Kenny, and Reuter 2017, and Dräger and Nghiem 2018).[14] We empirically reexamine this relationship using the "Preference Parameters Study" which provides more precise information on households' inflation expectations in the form of responses in numerical ranges than the Opinion Survey. For the estimation, we use the mid-point of the numerical range of each response category. A detailed description of variables used is provided in Table 1(b). Using ordinary least squares, we estimate the following equation:

$$y^e_{i,t} = \beta_1 \pi^e_{i,t} + \beta_2 \pi^e_{i,t} D_{LC} + \beta_3 D_{LC} + \mathbf{x}_{i,t}\gamma + \epsilon_{i,t}$$

where $y^e_{i,t}$ is household i's expected growth rate of real spending over the next year $t+1$. The growth rate is calculated using households' reported expected nominal expenditure changes

[14] An exception is the study by Bachman, Berg, and Sims (2015). Examining consumers' readiness to spend, they find that households' consumption behavior is not consistent with an inter-temporal Euler equation.

and the expected inflation rate over the next year.[15] $\pi^e_{i,t}$ is the expected inflation rate. D_{LC} is a set of dummy variables for households' income or asset holdings, which represent the extent to which households are liquidity constrained. Regarding income, households are divided into the following three groups based on the income per household member: (i) less than 1.5 million yen, (ii) from 1.5 to 3.0 million yen, and (iii) more than 3.0 million yen.[16] As an alternative, we use a variable representing households' asset holdings. The variable takes a value of one when a household holds financial assets worth less than 2.5 million yen, and zero otherwise.[17] $\mathbf{x}_{i,t}$ represents other control variables, including expected real income changes and current nominal income changes that households report in the survey.[18,19] Further, we add a dummy variable for households planning large expenses in the near future to control for a temporary spike in household spending. $\epsilon_{i,t}$ is the error term.

Table 2 shows the results of the estimation. In columns (2), (4), and (6), household fixed effects are controlled for to examine whether the results remain broadly unchanged. We find that in columns (1) and (2), which present the baseline estimation, the coefficient on inflation expectations is negative and statistically significant. This is consistent with the conjecture that higher inflation expectations boost consumption in the current year relative to consumption in the following year, thus restraining future consumption. Next, in columns (3) and (4) we examine the effect of liquidity constraints on the relationship between inflation expectations and future consumption by examining the interaction terms of inflation expectations and the dummy variables for income per household member. Both for the lowest

[15] The reason is that the survey does not provide data on changes in prices in the survey year relative to the preceding year and we cannot calculate the change in real spending in the survey year relative to the preceding year. We therefore use the expected change in real spending instead to examine if higher inflation expectations dampen future consumption. Ichiue and Nishiguchi (2014) provide evidence that higher inflation expectations stimulate current consumption and suppress future consumption.

[16] The dummy variables representing the degree to which households are liquidity constrained are computed as "household income" divided by "the number of household members." In the survey, households indicate their income by choosing a range category, and we convert this information into numerical data by using the mid-point of each range. For the highest category, which has an open-ended range of "more than 20 million yen," we assume that "more than 20 million yen"= 21 million yen by adding half of the interval (1 million) to the cut-off value following conventional practice (see, Boero, Smith, and Wallis 2015). The same approach is used for other multiple choice variables expressed in a range.

[17] Financial assets include savings, stocks, insurance policies, etc.

[18] Expected real income changes are calculated using households' reported expected nominal income changes and the expected inflation rate. Current income changes are in nominal terms because households do not report price changes compared to one year ago and an appropriate deflator for computing real income changes is not available.

[19] Past empirical studies show that temporal income changes also influence the inter-temporal substitution of consumption due to rule-of-thumb decision-making by consumers. Our main results remains unchanged when we omit the term of nominal income changes.

income group (income of less than 1.5 million yen) and the middle income group (from 1.5 to 3.0 million yen) the interaction term is positive and significant, suggesting that households with relatively tighter liquidity constraints are less likely to adjust their consumption than those that are not liquidity constrained (the highest income group; i.e., those with income of 3.0 million yen or more). Column (5) and (6) show the results when using the dummy variable representing asset holdings instead. We find that the results remain essentially unchanged. This suggests that it does not matter whether liquidity constraints are measured in terms of households' income or asset holdings, and that the income level can work as a measure of the degree to which households are liquidity constrained. This provides support for the validity of our empirical exercise in the next subsection, where we use income groups to represent liquidity constraints.

The above results show that when households are liquidity constrained, they cannot adjust their consumption, and the effect of inflation expectations on consumptions diminishes. This finding is consistent with our model. The results also suggest that our income categories capture the extent to which households are liquidity constrained, and we therefore use these categories in the following sections to represent liquidity constrained households.

4.3 Statistical Tests of the Theoretical Predictions

In this subsection, we empirically examine our two theoretical predictions.

4.3.1 The Liquidity Constraint and Inflation Expectations

We start by testing whether the inflation expectations of lower-income households are more sensitive to changes in their inflation perceptions. We examine this by estimating an ordered probit model using the Opinion Survey data. We assume that unobserved expectations of changes in the price level $\pi^{e*}_{i,t}$ are related to the discrete observed survey responses $\pi^{e}_{i,t}$ in the following way:

$$\pi^{e}_{i,t} = \begin{cases} 2 \text{ (Price level will go up significantly)} & \text{if } \alpha_4 < \pi^{e*}_{i,t} \\ 1 \text{ (Price level will go up slightly)} & \text{if } \alpha_3 < \pi^{e*}_{i,t} \leq \alpha_4 \\ 0 \text{ (Price level will remain almost unchanged)} & \text{if } \alpha_2 < \pi^{e*}_{i,t} \leq \alpha_3 \\ -1 \text{ (Price level will go down slightly)} & \text{if } \alpha_1 < \pi^{e*}_{i,t} \leq \alpha_2 \\ -2 \text{ (Price level will go down significantly)} & \text{if } \pi^{e*}_{i,t} \leq \alpha_1 \end{cases}$$

with cut-off parameters α_1, α_2, α_3, and α_4.

We assume that unobserved expectations of changes in the price level $\pi^{e*}_{i,t}$ are determined as follows:

$$\pi^{e*}_{i,t} = \beta_4 \pi^{p}_{i,t} + \beta_5 \pi^{p}_{i,t} D_{LC} + \beta_6 D_{LC} + \mathbf{x}_{i,t}\gamma + \epsilon_{i,t},$$

where $\pi^{e*}_{i,t}$ is household i's expected inflation rate over the coming year at time t. $\pi^{p}_{i,t}$ is the household's perceived change in the price level compared to one year ago.[20] D_{LC} is a dummy variable for liquidity constrained households. We use income categories to measure the degree to which households are liquidity constrained, since the Opinion Survey does not contain data on households' asset holdings. Similar to the exercise in the preliminary analysis, households are divided into the following three categories based on the income per household member: (i) less than 1.5 million yen, (ii) from 1.5 to 3.0 million yen, and (iii) more than 3.0 million yen.[21] Other control variables include respondents' age, gender, and work status, all of which may influence their inflation expectations. The variables used in the estimation are explained in detail in Table 1(a).

The results of the estimation are presented in Table 3. The table shows the coefficient estimates, with robust standard errors in parentheses. The coefficients on the dummy variable for the lowest income group are positive and significant, suggesting that liquidity constrained households are more likely to put weight on the perceived inflation rate when forming their inflation expectations than households that are not liquidity constrained. In addition to coefficient estimates, the table also shows marginal effects. Looking at the results in column (1), the marginal effect for "Perceived price changes" is 9.43 percent for the baseline income group (more than 3.0 million yen), which implies that a one-unit increase in perceived price changes on average is associated with a 9.43 percent increase in the probability that the household will choose the answer "Will go up significantly" in the question about expected

[20] Respondents are asked to choose among the following five answers regarding their perceived inflation rate: Prices (a) Have gone up significantly, (b) Have gone up slightly, (c) Have remained almost unchanged, (d) Have gone down slightly, and (e) Have gone down significantly.

[21] As above, the dummy variable for liquidity constrained households is computed as "household income" divided by "the number of household members." In the Opinion Survey, households are not asked about the exact number of household members. Instead, they are asked about the composition of their household and to choose among the following five categories: (a) Single-person household, (b) Married-couple household, (c) Two-generation household, (d) Three-generation household, and (e) Other. To calculate the income per household member, we assume that the number of household members is one in the case of (a), two in the case of (b), and three in the case of (c), (d), and (e). In Appendix Table 1, we present estimation results when using alternative ways to calculate household income to check the robustness of our results. We find that the results remain essentially unchanged. Regarding household income, households are given a choice of various income ranges, which we convert into numerical data by using the mid-point of each range. The largest income category, "10 million yen or greater," is open-ended, and we use a value of 10 million yen.

price changes over the next year. In addition, the interaction term of perceived price changes and income per household member shows that this probability for the lowest income households becomes approximately 10.96 (=9.43+1.53) percent. Column (2) presents the results for inflation expectations over the next five years, showing that the effect of perceived price changes on five-year-ahead inflation expectations is smaller than that in one-year-ahead inflation expectations. This effect is larger in the lowest income group, which is consistent with the result in column (1).

There may be other factors that are correlated with expected and perceived inflation rates. One possible factor is that households with greater financial literacy pay less attention to current inflation when forming their inflation expectations than other households. To control for this effect, in columns (3) and (4) we add a dummy variable for households with greater financial literacy as well as an interaction term of this dummy with inflation perceptions. The results for liquidity constrained households remain unchanged.[22,23] Other than the main results, the coefficient on the interaction term of the dummy for greater financial literacy and perceived inflation is insignificant in column (3) focusing on inflation expectations over the next year. However, in column (4) focusing on inflation expectations over the next five years, the coefficient is negative and significant, indicating that households with greater financial literacy pay less attention to perceived inflation when forming longer-term inflation expectations than other households. Moreover, looking at the results for other variables, we find that older people have higher inflation expectations, which is consistent with results obtained by Malmendier and Nagel (2016) and Diamond, Watanabe, and Watanabe (2018).

4.3.2 The Liquidity Constraint and Attention to the Inflation Target

Next, we examine the second theoretical prediction, namely, that more liquidity constrained households tend to focus less on the long-run target rate of inflation set by the central bank.

We employ an ordered probit model, assuming that there is a relationship between an unobserved variable and the degree of attention to monetary policy. In the baseline case, in

[22]The dummy variable for greater financial literacy takes one when respondents answered that their assessment of the economic situation is "based on economic indicators and statistics."

[23]To check the robustness of the results regarding the calculation of income per household member, Appendix Table 1 present results based on alternative calculations. In columns (1) and (2), we exclude household types (c), (d), and (e), so that observations are limited to households for which the exact number of household members is clear. In columns (3) and (4), we do not use any information on the number of household members and use total household income instead of household income per family member. The results using these alternative calculations for income categories are similar to the main results and therefore confirm their robustness.

which we use respondents' awareness about the Bank of Japan's inflation target as a proxy for attention to monetary policy, $AT^*_{i,t}$ and the discrete observable responses $AT_{i,t}$ are defined as follows:

$$AT_{i,t} = \begin{cases} 3 \text{ (Know about the inflation target)} & \text{if } \alpha_2 < AT^*_i \\ 2 \text{ (Do not know much about the inflation target)} & \text{if } \alpha_1 < AT^*_{i,t} \leq \alpha_2 \\ 1 \text{ (Have never heard of the inflation target)} & \text{if } AT^*_{i,t} \leq \alpha_1 \end{cases}$$

with cut-off parameters α_1 and α_2.

We examine whether the unobserved variable $AT^*_{i,t}$, attention to the inflation target, is determined in the following way. We use households' responses regarding their attentiveness to monetary policy and objectives. Specifically, we use the variable regarding awareness of the Bank of Japan's price stability target of 2 percent inflation as the dependent variable:

$$AT^*_{i,t} = \beta_7 D_{LC} + \mathbf{x}_{i,t}\gamma + \epsilon_{i,t},$$

where $AT^*_{i,t}$ represents household i's attention to the Bank's price stability target at time t. D_{LC} represents the dummy variables for income categories. $\mathbf{x}_{i,t}$ represents other control variables, including the variable for financial literacy so as to take into account that households' financial literacy may also influence the degree of attention they pay to the Bank's policies. Variables for respondents' age, gender, and work status are also added. The variables used in the estimation are explained in detail in Table 1(a).

Table 4 presents the results. Consistent with our theoretical prediction, they show that households with lower income pay less attention to the price stability target. Specifically, as shown in columns (1) and (2), lower income households (those with an income of less than 1.5 million yen per household member) display a more than 10 percentage point lower probability of answering that they know about price stability target of 2 percent. The difference between columns (1) and (2) is that the latter includes "high financial literacy" as an additional variable to test the robustness of the results. We find that high financial literacy has a substantial positive impact on the probability that households answered that they knew about the price stability target of 2 percent. More importantly, the result for lower income households remains essentially unchanged, indicating that our estimates are robust. The remaining six columns show the results when we use three alternative variables to represent households' attention to central bank policies. The three variables are awareness that the Bank of Japan's objective is to achieve price stability; interest in the Bank's activities; and the BOJ's relationship to our lives. Again, two specifications for each variable – excluding and

including "high financial literacy"– are estimated.[24] We obtain similar results to the baseline specification. Added to this, we also corroborate that the above results are robust when we control for the effect of financial literacy on the attentiveness to the Bank's policies.[25]

5 Discussion

The results of the analysis in the preceding section imply that our model is valid in that it is consistent with the empirical facts. That is, the degree of households' liquidity constraint is a key determinant of their inflation expectations. Using the same model, this section attempts to derive further implications.

5.1 Policy Implications

We start by discussing the policy implications of our findings. Our theoretical analysis and results in Figures 1 and 2 suggest that alleviating households' liquidity constraint increases their incentive to form precise expectations on future inflation, since it increases the expected loss from imprecise inflation expectations. Therefore, if the central bank can alleviate households' liquidity constraint through monetary easing, households will allocate more attention to information on the inflation rate the central bank aims to achieve in the long run, including messages emitted by the central bank. In this case, the bank would be able to more firmly anchor households' inflation expectations.

Another measure implied by our findings is that central banks should try to reduce information processing costs for households, for example by using language that is easier to understand and by being more transparent in their communication. To illustrate this point, Figure 3(a) depicts the link between changes in the optimal allocation of attention and the cost of processing information about the inflation rate the central bank aims to

[24] Concretely, the questions and possible responses are as follows. Regarding the question "Do you know that one of the Bank's objectives is to achieve price stability?" the possible responses are: 1. Have never heard of it; 2. Have read or heard of it, but do not know much about it; and 3. Know about it. Regarding the question "How would you describe your level of interest in the Bank's activities?" the possible response are: 1. Not interested; 2. Not particularly interested; 3. Difficult to say; 4. Somewhat interested; and 5. Interested. Finally, regarding the question "How would you describe the Bank's relationships to our lives?" the possible responses are: 1. Not Related; 2. Not particularly related; 3. Difficult to say; 4. Somewhat Related; and 5. Related.

[25] As is in the Appendix Table 1, we check the robustness of the results regarding the calculation of income per household member. In Appendix Table 2, we show the results when we do not use any information on the number of household members and use total household income instead of household income per family member. The results using this alternative calculation for income categories is similar to the main results and therefore confirm their robustness.

achieve in the long run, Ω, while Figure 3(b) shows how the relationship between inflation perceptions and expectations changes along with Ω. We set $\sigma_\epsilon^2 = 4$, $\sigma_{\pi^*}^2 = 0.25$, $\sigma_x^2 = 1$, $\kappa = 1$, $\Gamma = 0.05$, $\theta = 0.25$, and $\rho = 0.25$. In the figure, we allow Ω to vary from zero to two. Importantly, when Ω is above a certain value, a decrease in Ω makes households allocate more attention to information on the inflation rate the central bank aims to achieve in the long run and less attention to the distribution of prices in the current period (Figure 3(a)). As a result, households' inflation expectations become less sensitive to changes in their inflation perceptions as the central bank reduces information processing costs Ω more (Figure 3(b)). On the other hand, if Ω is below a certain value, then both $\left(\sigma_{x|s}^{-2}\right)^*$ and $\left(\sigma_{\pi^*|s}^{-2}\right)^*$ increase as Ω becomes smaller, because households now can obtain precise information on the inflation rate the central bank aims to achieve in the long run at a lower cost and allocate a larger amount of their attention to the distribution of prices in the current period (Figure 3(a)). Therefore, the decrease in Ω leads to higher comovement between households' inflation perceptions and inflation expectations.

[Figure 3 about here]

5.2 Aggregate Inflation Dynamics and Inflation Expectations

Our model is also useful to account for international differences in the degree to which inflation expectations are anchored. Specifically, our model predicts that the inflation expectations of households in an economy with more persistent inflation dynamics are more susceptible to inflation perceptions. This is illustrated in Figure 4, where panel (a) shows how the optimal attention allocation changes in response to changes in the persistence of inflation dynamics ρ, while panel (b) plots how the relationship between inflation perceptions and expectations changes as ρ changes. For the figure, we set $\sigma_\epsilon^2 = 4$, $\sigma_{\pi^*}^2 = 0.25$, $\sigma_x^2 = 1$, $\kappa = 1$, $\Gamma = 0.05$, $\theta = 0.25$ and $\Omega = 1$, and we allow ρ to vary from zero to one. The panels show that households allocate more attention to the price distribution of the homogeneous good rather than the inflation rate that the central bank aims to achieve in the long run as inflation dynamics become more persistent. Inflation expectations become more dependent on inflation perceptions as ρ increases.

[Figure 4 about here]

6 Concluding Remarks

This paper addresses one of the most important questions in the macroeconomic literature: how do households form their inflation expectations? We proposed a rational inattention model of a household that attempts to minimize the expected loss from insufficient bargain-hunting and inefficient inter-temporal consumption allocation. The household allocates its attention to information about two variables: the lowest price in the current period and the aggregate inflation rate that the central bank aims to achieve in the long run.

The model yields two hypotheses: (1) that the inflation expectations of households subject to a tighter liquidity constraint should be more closely correlated with their inflation perceptions; and (2) that such households are also less attentive to information about the inflation rate the central bank aims to achieve in the long run. We empirically validated the model by testing these predictions using a micro dataset on Japanese households. Finally, we reached the important implication for policy that alleviation of households' liquidity constraint through monetary easing could influence households' optimal attention allocation and thus promotes more effective central bank communication regarding the inflation rate it aims to achieve.

Our model can be extended in multiple directions. One possible extension would be to develop a general equilibrium model to explore the interaction between households' attention allocation and inflation dynamics. Another extension would be to endogenize the mechanism underlying the difference in the extent to which households are liquidity constrained. Further, it would also be useful to test our model using data on households in other countries to confirm its validity and to gain a better understand of the inflation expectations formation process of households and the mechanisms involved in anchoring/de-anchoring households' inflation expectations.

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A Proofs

A.1 Proof of Lemma 1

This appendix provides the proof of Lemma 1. We start by transforming the budget constraint as follows:

$$C_0\chi_0 + \frac{1}{R_1}C_1\chi_1 = I + \frac{1}{R_1}I.$$

From the first order conditions with respect to C_0 and C_1, the inter-temporal Euler equation is given by

$$\mathbb{E}_0\left[\frac{C_0^*}{C_1^*}\right] = \mathbb{E}_0\left[\frac{1}{R_1}\right]\frac{\chi_1}{\chi_0}.$$

The gross real interest rate is one in steady state ($R_{ss} = \beta^{-1} = 1$). Thus, the log-linearized condition around the steady state values C_{ss}, R_{ss}, and $\chi_{ss}(=1)$ is

$$c_0^* - \mathbb{E}_0[c_1^*] = -\mathbb{E}_0[r_1] + x_1 - x_0.$$

The log-linearized budget constraint around the steady state values is

$$c_0^* + c_1^* + x_0 + x_1 = 0.$$

Therefore, the conditions are expressed as follows:

$$\begin{aligned} c_0^* &= -\frac{1}{2}\mathbb{E}_0[r_1] - x_0, \\ \mathbb{E}_0[c_1^*] &= \frac{1}{2}\mathbb{E}_0[r_1] - x_1. \end{aligned}$$

In a perfect information environment, $x_0 = x_1 = 0$ holds. From the assumption that the household needs to purchase the good at the same store in period $t = 1$, $x_1 = x_0$ holds.

By substituting the Fisher equation $r_1 = i_0 - \mathbb{E}_0[\pi_1]$ into the conditions and by assuming $i_0 = 0$, we obtain

$$\begin{aligned} c_0^* &= \frac{1}{2}\mathbb{E}_0[\pi_1] - x_0, \\ \mathbb{E}_0[c_1^*] &= -\frac{1}{2}\mathbb{E}_0[\pi_1] - x_0. \end{aligned}$$

With the liquidity constraint, the upper bound of c_0 is determined as follows. To begin with, the steady state value of consumption, C_{ss}, is given by

$$C_{ss}\chi_{ss} + \frac{1}{R_{ss}}C_{ss}\chi_{ss} = I + \frac{1}{R_{ss}}I \Leftrightarrow C_{ss} = I.$$

Therefore, using the first-order approximation of $\ln(1+\theta)$ around $\theta = 0$, that is, $\ln(1+\theta) \approx \theta$, the upper bound of $c_0^* + x_0$ is given by

$$\begin{aligned} \ln\left(C_0^* \chi_0 / C_{ss} \chi_{ss}\right) &\leq \ln(1+\theta) \approx \theta \\ &\Leftrightarrow \quad c_0^* + x_0 \leq \theta. \end{aligned}$$

Similarly, the lower bound of $c_1^* + x_1$, using $R_1 \approx 1$, is given by

$$\begin{aligned} \ln\left(C_1^* \chi_1 / C_{ss} \chi_{ss}\right) &\geq \ln(1 - R_1\theta) \approx -\theta \\ &\Leftrightarrow \quad c_1^* + x_1 \geq -\theta. \end{aligned}$$

Using $x_1 = x_0$, we obtain the following conditions:

$$\begin{aligned} c_0^* + x_0 &= \min\left\{\frac{1}{2}\mathbb{E}_0\left[\pi_1\right], \theta\right\} \Leftrightarrow c_0^* = \min\left\{\frac{1}{2}\mathbb{E}_0\left[\pi_1\right], \theta\right\} - x_0, \\ \mathbb{E}_0\left[c_1^*\right] + x_0 &= \max\left\{-\frac{1}{2}\mathbb{E}_0\left[\pi_1\right], -\theta\right\} \Leftrightarrow \mathbb{E}_0\left[c_1^*\right] = \max\left\{-\frac{1}{2}\mathbb{E}_0\left[\pi_1\right], -\theta\right\} - x_0. \square \end{aligned}$$

A.2 Proof of Lemma 2

Next, we provide the proof of Lemma 2. The expected loss caused by the imperfect information structure is approximated around the solution under perfect information as follows:

$$\mathbb{EL} \approx -\mathbb{E}\left[\ln\left(C_0^*/C_0^{**}\right) + \ln\left(C_1^*/C_1^{**}\right) - \frac{1}{2}\left(\ln\left(C_0^*/C_0^{**}\right)\right)^2 - \frac{1}{2}\left(\ln\left(C_1^*/C_1^{**}\right)\right)^2\right].$$

Substituting the conditions in Lemma (1) into the expected loss, we obtain

$$\begin{aligned} \mathbb{EL} &\approx -\mathbb{E}\left[\ln\left(C_0^*/C_0^{**}\right) + \ln\left(C_1^*/C_1^{**}\right) - \frac{1}{2}\left(\ln\left(C_0^*/C_0^{**}\right)\right)^2 - \frac{1}{2}\left(\ln\left(C_1^*/C_1^{**}\right)\right)^2\right] \\ &\approx -\mathbb{E}\left[\widehat{c}_0 + \widehat{c}_1\right] + \frac{1}{2}\mathbb{E}\left[\left(\widehat{c}_0\right)^2 + \left(\widehat{c}_1\right)^2\right] \\ &= 2\mathbb{E}\left[x_0\right] + \frac{1}{2}\mathbb{E}\left[2x_0^2 + 2\left(\min\left\{\frac{1}{2}\mathbb{E}_0\left[\pi_1\right], \theta\right\} - \min\left\{\frac{1}{2}\pi_1, \theta\right\}\right)^2\right] \\ &= \mathbb{E}\left[2x_0 + x_0^2\right] + \mathbb{E}\left[\left(\min\left\{\frac{1}{2}\mathbb{E}_0\left[\pi_1\right], \theta\right\} - \min\left\{\frac{1}{2}\pi_1, \theta\right\}\right)^2\right]. \square \end{aligned}$$

A.3 Approximation of the Loss Function

Define $f_\pi \equiv \mathbb{E}\left[\left(\min\left\{\mathbb{E}_0\left[\pi_1\right]/2, \theta\right\} - \min\left\{\pi_1/2, \theta\right\}\right)^2\right]$, $\Psi \equiv \left(\mathbb{E}_0\left[\pi_1\right] - \pi_1\right)/2$, and $\Upsilon \equiv \theta - \pi_1/2$. π_1 and Ψ follow a Gaussian distribution with mean zero and are consistent with

Gaussian shocks and noises. Then, for $\Upsilon \geq 0$, for any fixed π_1, f_π is given by

$$\int_{-\infty}^{\Upsilon} \Psi^2 pdf\left(\Psi\right) d\Psi + \Upsilon^2 \int_{\Upsilon}^{\infty} pdf\left(\Psi\right) d\Psi$$

and for $\Upsilon < 0$ by

$$\int_{-\infty}^{\Upsilon} \left(\Psi - \Upsilon\right)^2 pdf\left(\Psi\right) d\Psi.$$

To sum up, we obtain

$$\begin{aligned} f_\pi \equiv & \int_0^{\infty} \left[\int_{-\infty}^{\Upsilon} \Psi^2 pdf\left(\Psi\right) d\Psi + \Upsilon^2 \int_{\Upsilon}^{\infty} pdf\left(\Psi\right) d\Psi \right] pdf\left(\Upsilon\right) d\Upsilon \\ & + \int_{-\infty}^{0} \left[\int_{-\infty}^{\Upsilon} \left(\Psi - \Upsilon\right)^2 pdf\left(\Psi\right) d\Psi + 0 \int_{\Upsilon}^{\infty} pdf\left(\Psi\right) d\Psi \right] pdf\left(\Upsilon\right) d\Upsilon \end{aligned}$$

Because $\Upsilon \equiv \theta - \pi_1/2$ is increasing in θ, f_π is increasing in θ as well. We assume that $\left(\mathbb{E}_0\left[\pi_1\right]/2\right)^2$ and $\left(\pi_1/2\right)^2$ take a value greater than one with almost zero probability. Therefore, the upper bound of f_π is approximated by $\mathbb{E}\left[\Psi^2\right]$ at $\theta = 1$. On the other hand, the lower bound depends not only on θ but also on the realization of π_1, while $\theta = 0$ finds the lower bound for any π_1. As an approximation, we assume that f_π is linear in θ. We assume that the lower bound of the approximated f_π is the value of f_π at $\pi_1 = 0$, that is, $\mathbb{E}\left[\Psi^2\right]/2$ at $\theta = 0$, because the mean, median, and mode of π_1 are all zero. The upper bound is set to be $\mathbb{E}\left[\Psi^2\right]$ at $\theta = 1$. Then f_π is approximated as follows:

$$\begin{aligned} f_\pi \approx & \frac{1}{2}\mathbb{E}\left[\Psi^2\right]\left(1+\theta\right) \\ = & \frac{1}{2}\left(1+\theta\right)\mathbb{E}\left[\left(\frac{1}{2}\mathbb{E}_0\left[\pi_1\right] - \frac{1}{2}\pi_1\right)^2\right] \\ = & \frac{1+\theta}{8}\mathbb{E}\left[\left(\mathbb{E}_0\left[\pi_1\right] - \pi_1\right)^2\right]. \end{aligned}$$

Moreover, we numerically calculate and compare the approximated function $\widetilde{f_\pi}$ to the exact function f_π as follows. In Figure A.1(a), θ is fixed and, in each trial ($n \in \{1, 2, ..., 10^6\}$), we generate $\Upsilon \sim \mathcal{N}(\theta, \mathbb{V}_{\pi_1}/4)$, and $\Psi \sim \mathcal{N}(0, \mathbb{V}_\Psi)$ under $\mathbb{V}_{\pi_1} = 0.5$ and $\mathbb{V}_\Psi = 0.25$, and numerically count $\widetilde{f_\pi}(n)$ as follows:

$$\widetilde{f_\pi}(n) = \begin{cases} \Upsilon^2 \text{ if } \Psi \geq \Upsilon \geq 0 \\ \Psi^2 \text{ if } \Upsilon \geq 0 \text{ and } \Upsilon \geq \Psi \\ \left(\Psi - \Upsilon\right)^2 \text{ if } \Psi \leq \Upsilon < 0 \\ 0 \text{ otherwise} \end{cases}.$$

We then calculate $1/10^6 \sum_{n=1}^{10^6} \widetilde{f_\pi}(n)$ for each $\theta \in [0, 1]$. Similarly, in Figure A.1(b), we calculate $1/10^6 \sum_{n=1}^{10^6} \widetilde{f_\pi}(n)$ for each fixed $\mathbb{V}_\Psi \in [0, 1]$ under $\mathbb{V}_{\pi_1} = 0.5$ and $\theta = 0.25$. As

shown in Figures A.1(a) and (b), the approximated values are close to the original values where θ and $\mathbb{V}_\Psi$ vary, justifying our approximation procedures.

[Figure A1 about here]

A.4 Proof of Proposition 1

(i) Given the information structures, the household's expectations regarding the inflation rate the central bank aims to achieve in the long run π^* are updated as follows: $\pi^*(s) \sim \mathcal{N}(\pi^*, \sigma^2_{\pi^*|s})$ where

$$\begin{aligned}\mathbb{E}_0\left[\pi^*\right] &= \pi^*(s),\\ \mathbb{V}_0^{-1}\left[\pi^*\right] &= \sigma^{-2}_{\pi^*|s}.\end{aligned}$$

Inflation perceptions are represented by $\widetilde{\pi}_0 \sim \mathcal{N}(\pi_0, \sigma^2_{x|s})$. The precision of the priors is given by $\sigma^{-2}_{\pi^*}$ and σ^{-2}_x.

Given these information structures, *aggregate* inflation perceptions are given by the following:

$$\begin{aligned}\mathbb{E}_0\left[\pi_0\right] &= \frac{\sigma^{-2}_{x|s}}{\sigma^{-2}_{x|s} + \left[(1-\rho)^2\sigma^2_{\pi^*|s} + \sigma^2_\epsilon\right]^{-1}}\widetilde{\pi}_0\\ &\quad + \frac{\left[(1-\rho)^2\sigma^2_{\pi^*|s} + \sigma^2_\epsilon\right]^{-1}}{\sigma^{-2}_{x|s} + \left[(1-\rho)^2\sigma^2_{\pi^*|s} + \sigma^2_\epsilon\right]^{-1}}(1-\rho)\pi^*(s)\\ &= \lambda\widetilde{\pi}_0 + (1-\lambda)(1-\rho)\pi^*(s),\\ \mathbb{V}_0\left[\pi_0\right] &= \frac{1}{\sigma^{-2}_{x|s} + \left[(1-\rho)^2\sigma^2_{\pi^*|s} + \sigma^2_\epsilon\right]^{-1}}.\end{aligned}$$

Given *aggregate* inflation perceptions, inflation expectations are given by

$$\begin{aligned}\mathbb{E}_0\left[\pi_1\right] &= \rho\mathbb{E}_0\left[\pi_0\right] + (1-\rho)\mathbb{E}_0\left[\pi^*\right]\\ &= \rho\left(\lambda\widetilde{\pi}_0 + (1-\lambda)(1-\rho)\pi^*(s)\right) + (1-\rho)\pi^*(s)\\ &= \rho\lambda\widetilde{\pi}_0 + (1-\rho)\left[1+\rho(1-\lambda)\right]\pi^*(s)\end{aligned}$$

and, because

$$\begin{aligned}&\mathbb{E}\left[\left(\lambda\widetilde{\pi}_0 + (1-\lambda)(1-\rho)\pi^*(s) - \pi_0\right)^2\right]\\ =\ &\mathbb{E}\left[\left(\lambda\left(\widetilde{\pi}_0 - \pi_0\right) + (1-\lambda)\left((1-\rho)\left(\pi^*(s) - \pi^*\right) - \epsilon_0\right)\right)^2\right]\\ =\ &\lambda^2\sigma^2_{x|s} + (1-\lambda)^2(1-\rho)^2\sigma^2_{\pi^*|s} + (1-\lambda)^2\sigma^2_\epsilon,\end{aligned}$$

$\mathbb{V}_0[\pi_1]$ is

$$\begin{aligned}\mathbb{V}_0[\pi_1] &= \rho^2\lambda^2\sigma^2_{x|s} + (1-\rho)^2[1+\rho(1-\lambda)]^2\sigma^2_{\pi^*|s} \\ &\quad +\rho^2(1-\lambda)^2\sigma^2_\epsilon.\end{aligned}$$

Moreover, the fourth order moment of the Gaussian $\mathbb{E}\left[\left(\frac{1}{n}\sum_{i=1}^n p_0(i) - p_0\right)^4\right]$ is equal to $3\mathbb{E}\left[\left(\frac{1}{n}\sum_{i=1}^n p_0(i) - p_0\right)^2\right]^2$.

Therefore, the attention allocation problem can be transformed as follows:

$$\min_{\left(\sigma^{-2}_{x|s},\sigma^{-2}_{\pi^*|s}\right)} \left[2\Gamma\sigma^2_{x|s} + 3\Gamma^2\left(\sigma^2_{x|s}\right)^2 + \frac{1+\theta}{8}\left(\begin{array}{c}\rho^2\lambda^2\sigma^2_{x|s} + (1-\rho)^2[1+\rho(1-\lambda)]^2\sigma^2_{\pi^*|s} \\ +\rho^2(1-\lambda)^2\sigma^2_\epsilon\end{array}\right)\right]$$

where

$$\lambda \equiv \frac{\sigma^{-2}_{x|s}}{\sigma^{-2}_{x|s} + \left[(1-\rho)^2\sigma^2_{\pi^*|s} + \sigma^2_\epsilon\right]^{-1}},$$

and

$$s.t.\ \frac{1}{2}\log_2\left(\frac{\sigma^{-2}_{x|s}}{\sigma^{-2}_x}\right) + \Omega\frac{1}{2}\log_2\left(\frac{\sigma^{-2}_{\pi^*|s}}{\sigma^{-2}_{\pi^*}}\right) \leq \kappa.$$

Because the inequality binds due to the monotonicity of the utility function with respect to the amount of consumption, we obtain

$$\begin{aligned}&\frac{1}{2}\log_2\left(\frac{\sigma^{-2}_{x|s}}{\sigma^{-2}_x}\right) + \Omega\frac{1}{2}\log_2\left(\frac{\sigma^{-2}_{\pi^*|s}}{\sigma^{-2}_{\pi^*}}\right) = \kappa \\ \Leftrightarrow\ &\frac{\sigma^{-2}_{x|s}}{\sigma^{-2}_x}\left(\frac{\sigma^{-2}_{\pi^*|s}}{\sigma^{-2}_{\pi^*}}\right)^\Omega = 2^{2\kappa} \Leftrightarrow \sigma^{-2}_{\pi^*|s} = \sigma^{-2}_{\pi^*}\left(\frac{\sigma^{-2}_x}{\sigma^{-2}_{x|s}}2^{2\kappa}\right)^{\frac{1}{\Omega}}.\square\end{aligned}$$

(ii) We transform the allocation problem into

$$\min_{\left(\sigma^{-2}_{x|s},\sigma^{-2}_{\pi^*|s}\right)} \left[\begin{array}{c}\frac{2\Gamma}{2\Gamma+3\Gamma^2+\frac{1+\theta}{8}}\sigma^2_{x|s} + \frac{3\Gamma^2}{2\Gamma+3\Gamma^2+\frac{1+\theta}{8}}\left(\sigma^2_{x|s}\right)^2 \\ +\frac{\frac{1+\theta}{8}}{2\Gamma+3\Gamma^2+\frac{1+\theta}{8}}\left(\begin{array}{c}\rho^2\lambda^2\sigma^2_{x|s} + (1-\rho)^2[1+\rho(1-\lambda)]^2\sigma^2_{\pi^*|s} \\ +\rho^2(1-\lambda)^2\sigma^2_\epsilon\end{array}\right)\end{array}\right].$$

The optimal ratio $\left(\left(\sigma^{-2}_{x|s}\right)^* / \left(\sigma^{-2}_{\pi^*|s}\right)^*\right)$ for the three separable terms $\sigma^2_{x|s}$, $\left(\sigma^2_{x|s}\right)^2$, and

$$\rho^2\lambda^2\sigma^2_{x|s} + (1-\rho)^2[1+\rho(1-\lambda)]^2\sigma^2_{\pi^*|s} + \rho^2(1-\lambda)^2\sigma^2_\epsilon,$$

is, respectively, the corner solutions $2^{2\kappa}\sigma_x^{-2}/\sigma^{-2}_{\pi^*}$ and $2^{2\kappa}\sigma_x^{-2}/\sigma^{-2}_{\pi^*}$, and the internal solution $\left(\sigma^{-2}_{x|s}\right)^* / \left(\sigma^{-2}_{\pi^*|s}\right)^* \left(< 2^{2\kappa}\sigma_x^{-2}/\sigma^{-2}_{\pi^*}\right)$. Moreover, the weight on the term

$$\rho^2\lambda^2\sigma^2_{x|s} + (1-\rho)^2[1+\rho(1-\lambda)]^2\sigma^2_{\pi^*|s} + \rho^2(1-\lambda)^2\sigma^2_\epsilon,$$

increases as θ increases. Thus, it is obvious that the optimal ratio ($\left(\sigma_{x|s}^{-2}\right)^* / \left(\sigma_{\pi^*|s}^{-2}\right)^*$) decreases in θ. $\square$

A.5 Proof of Proposition 2

Inflation expectations are given by

$$\mathbb{E}_0\left[\pi_1\right] = \rho\lambda\widetilde{\pi}_0 + (1-\rho)\left[1+\rho\left(1-\lambda\right)\right]\mathbb{E}_0\left[\pi^*\right]$$

where

$$\begin{aligned}
\lambda &\equiv \frac{\left(\sigma_{x|s}^{-2}\right)^*}{\left(\sigma_{x|s}^{-2}\right)^* + \left[\left(1-\rho\right)^2\left(\sigma_{\pi^*|s}^2\right)^* + \sigma_\epsilon^2\right]^{-1}}, \\
\widetilde{\pi}_0 &= \left(1-\rho\right)\pi^* + \epsilon_0 + \delta_0(\pi_0), \\
\mathbb{E}_0\left[\pi^*\right] &= \pi^* + \delta_0(\pi^*).
\end{aligned}$$

Here, $\delta_0(\pi_0) \sim \mathcal{N}(0, \sigma_{x|s}^2)$ and $\delta_0(\pi^*) \sim \mathcal{N}\left(0, \sigma_{\pi^*|s}^2\right)$ represent the noise terms.

The covariance of $\mathbb{E}_0\left[\pi_1\right]$ and $\widetilde{\pi}_0$ and the variance of $\widetilde{\pi}_0$ are, respectively,

$$\begin{aligned}
&\mathbb{C}\left[\mathbb{E}_0\left[\pi_1\right], \widetilde{\pi}_0\right] \\
=\ &\mathbb{E}\left[\left(\rho\lambda\widetilde{\pi}_0 + (1-\rho)\left[1+\rho\left(1-\lambda\right)\right]\mathbb{E}_0\left[\pi^*\right]\right)\widetilde{\pi}_0\right] \\
=\ &\mathbb{E}\left[\begin{array}{c} \left(\left(1-\rho^2\right)\pi^* + \rho\lambda\epsilon_0 + \rho\lambda\delta_0(\pi_0) + (1-\rho)\left[1+\rho\left(1-\lambda\right)\right]\delta_0(\pi^*)\right) \\ \left(\left(1-\rho\right)\pi^* + \epsilon_0 + \delta_0(\pi_0)\right) \end{array}\right] \\
=\ &\left(1+\rho\right)\left(1-\rho\right)^2\sigma_{\pi^*}^2 + \rho\lambda\sigma_\epsilon^2 + \rho\lambda\left(\sigma_{x|s}^2\right)^*
\end{aligned}$$

and

$$\mathbb{V}\left[\widetilde{\pi}_0\right] = \left(1-\rho\right)^2\sigma_{\pi^*}^2 + \sigma_\epsilon^2 + \left(\sigma_{x|s}^2\right)^*.$$

Thus,

$$\gamma = \frac{\mathbb{C}\left[\mathbb{E}_0\left[\pi_1\right], \widetilde{\pi}_0\right]}{\mathbb{V}\left[\widetilde{\pi}_0\right]} = \frac{\left(1+\rho\right)\left(1-\rho\right)^2\sigma_{\pi^*}^2 + \rho\lambda\sigma_\epsilon^2 + \rho\lambda\left(\sigma_{x|s}^2\right)^*}{\left(1-\rho\right)^2\sigma_{\pi^*}^2 + \sigma_\epsilon^2 + \left(\sigma_{x|s}^2\right)^*}.\square$$

Figure 1: Liquidity constraint (θ) and precision of information on the distribution of prices in the current period and the inflation rate that the central bank aims to achieve in the long run

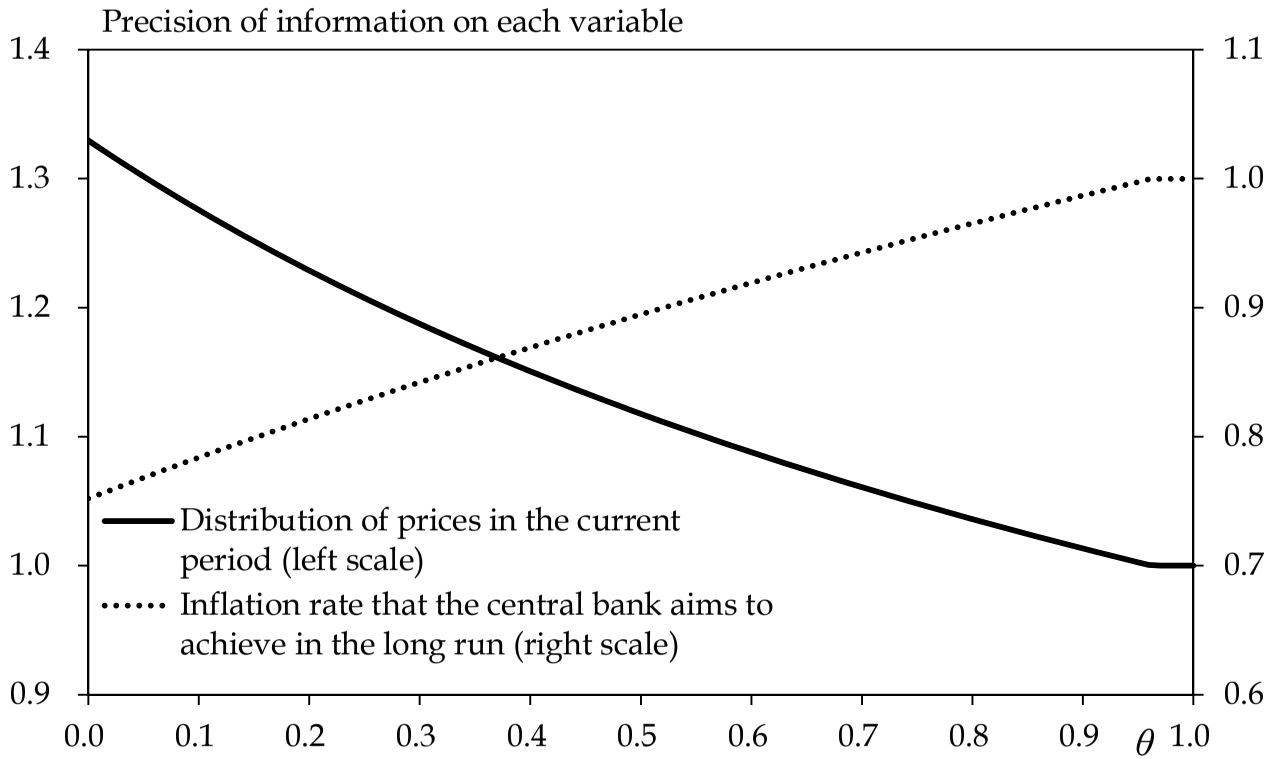


Figure 2: Liquidity constraint (θ) and the dependence of inflation expectations on inflation perceptions

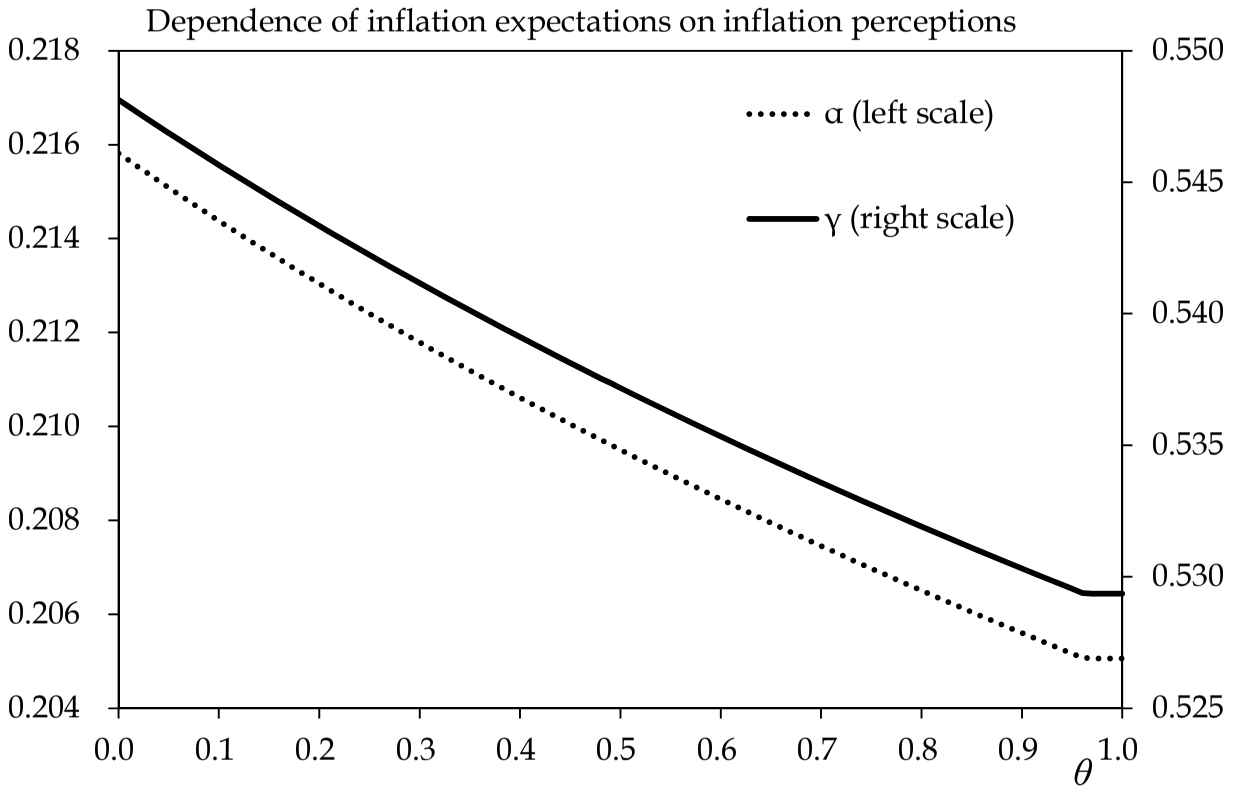
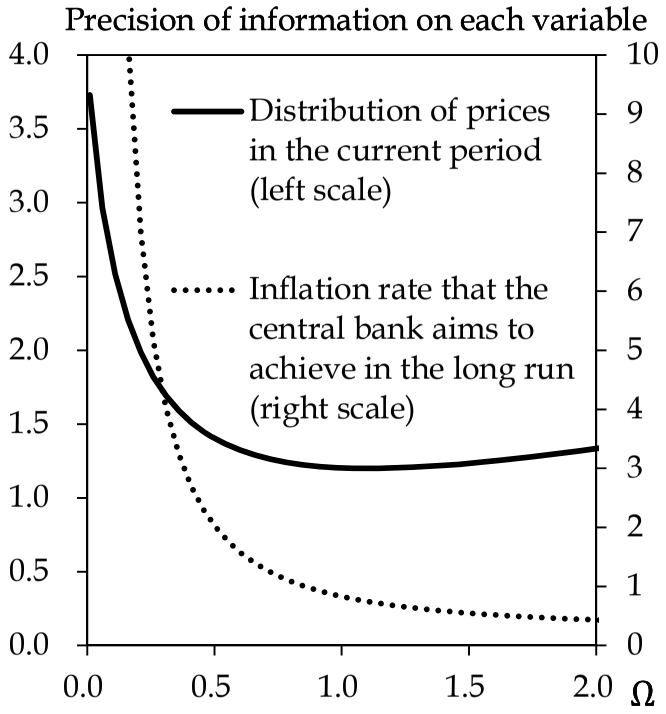


Figure 3: Costs of processing information (Ω) about the inflation rate that the central bank aims to achieve in the long run and inflation expectations

(a) Optimal attention allocation



(b) Inflation perceptions and inflation expectations

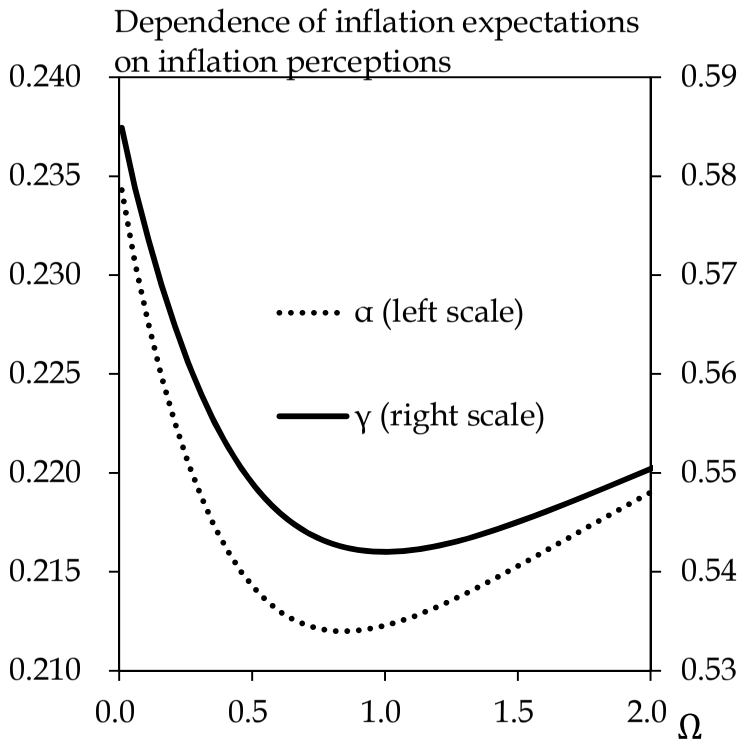
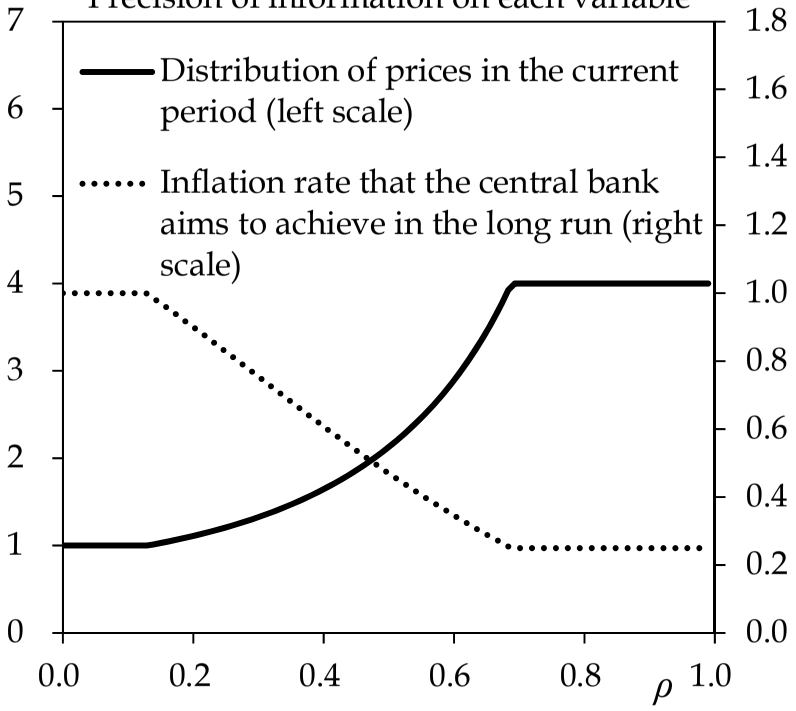


Figure 4: Persistence of inflation dynamics (ρ) and inflation expectations

(a) Optimal attention allocation



(b) Inflation perceptions and inflation expectations

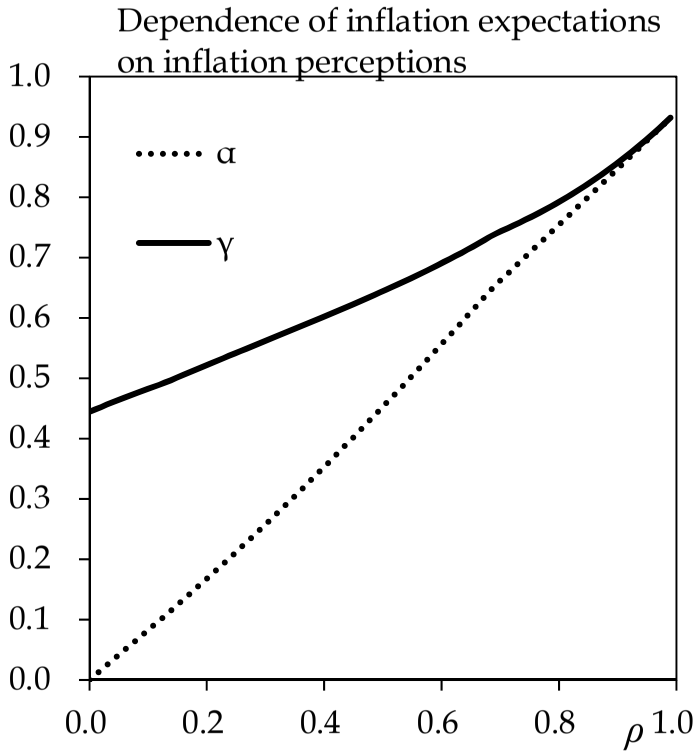


Figure A.1: Accuracy of approximated expected loss

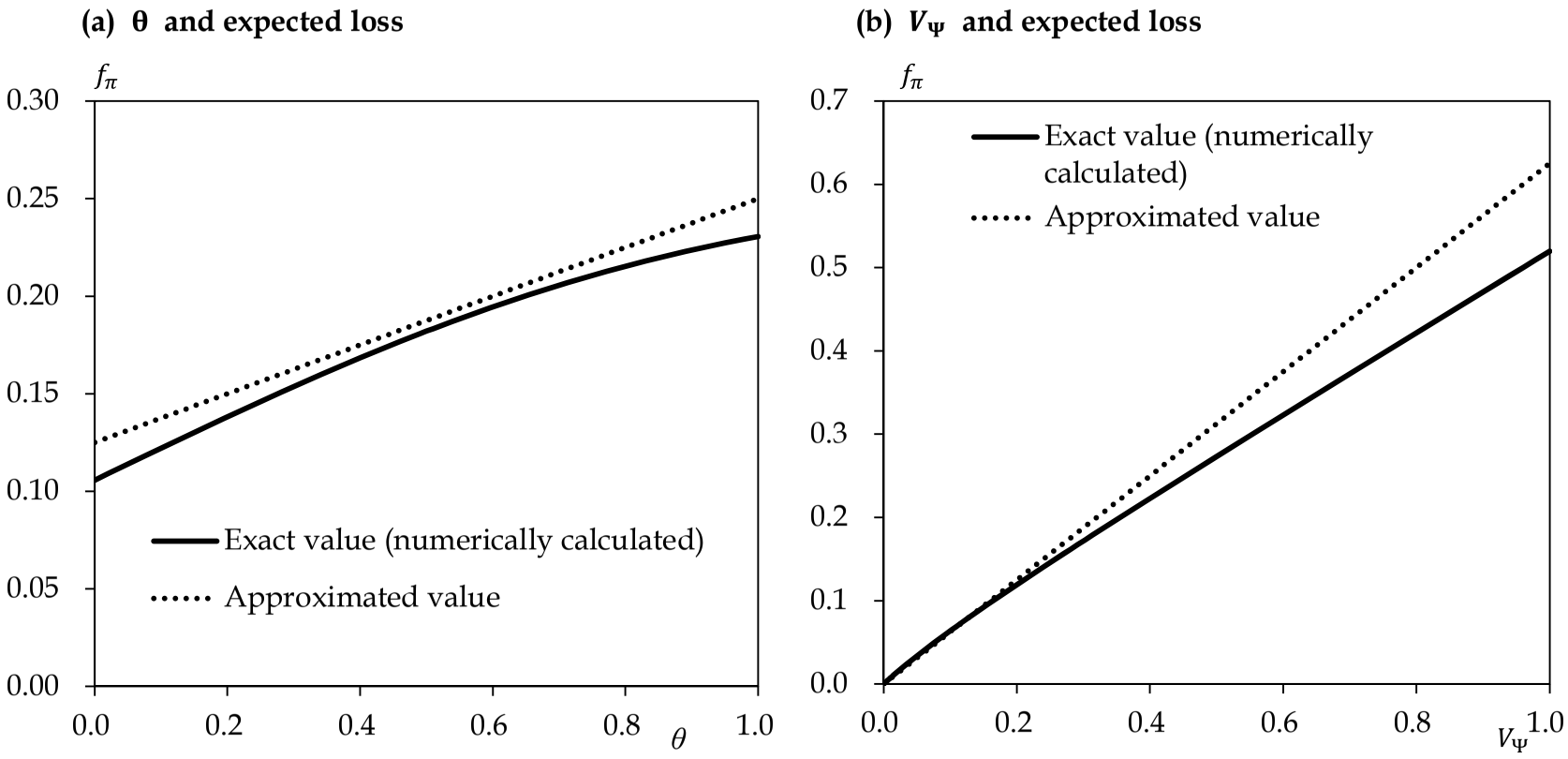


Table 1(a). Summary Statistics of Opinion Survey

Item	Numbers assigned to response categories	Obs.	Mean	Std. dev.	Min	Max
Expected price changes over the next year	Category [-2, -1, 0, 1, 2] (-2: Will go down significantly, -1: Will go down slightly, 0: Will remain almost unchanged, 1: Will go up slightly, 2: Will go up significantly)	107,721	0.65	0.83	-2	2
Perceived price changes compared with one year ago	Category [-2, -1, 0, 1, 2] (-2: Have gone down significantly, -1: Have gone down slightly, 0: Have remained almost unchanged, 1: Have gone up slightly, 2: Have gone up significantly)	107,518	0.73	0.73	-2	2
Knowledge of price stability target of 2 percent	Category [1, 2, 3] (1: Have never heard of it, 2: Have read or heard of it, but do not know much about it, 3: Know about it)	43,203	1.93	0.80	1	3
Knowledge that one of the Bank of Japan's objectives is to achieve price stability	Category [1, 2, 3] (1: Have never heard of it, 2: Have read or heard of it, but do not know much about it, 3: Know about it)	64,515	2.07	0.75	1	3
Interest in the the Bank's activities	Category [1, 2, 3, 4, 5] (1: Not interested, 2: Not particularly interested, 3: Difficult to say, 4: Somewhat interested, 5: Interested)	64,477	2.76	1.10	1	5
The Bank's relationship to our lives	Category [1, 2, 3, 4, 5] (1: Not related, 2: Not particularly related, 3: Difficult to say, 4: Somewhat related, 5: Related)	64,477	3.95	1.03	1	5
Items used for constructing dummy variables:						
Annual income of respondent and spouse (before taxes; excluding temporary income such as retirement allowance and income from land sales, but including pensions)	Category [0, 1.5, 4.0, 7.5, 10] Mil. yen	107,214	4.12	2.83	0	10
Composition of household	Category [1, 2, 3, 4, 5] (1: Single, 2: Married-couple, 3: Two-generation, 4:Three-generation, 5: Other)	107,924	2.67	0.89	1	5
Financial literacy	Category [1, 0]	108,535	0.11	0.31	0	1
Gender	Category [1, 2] (1: Male, 2: Female)	108,535	1.52	0.50	1	2
Age	Category [1, 2, 3, 4, 5, 6] (1: 20-29, 2: 30-39, 3: 40-49, 4: 50-59, 5: 60-69, 6: 70 or older)	108,535	3.79	1.61	1	6
Work status	Category [1, 2, 3, 4, 5] (1: Regular employee, 2: Working in agriculture, forestry, or fisheries, 3: Self-employed, working for a family business, or professional worker, 4: Non-regular employee (part-timer), 5: Other (e.g., full-time homeworker, student, pensioner, or unemployed))	107,367	3.13	1.75	1	5

Table 1(b). Summary Statistics of Preference Parameters Study

Items	Numbers assigned to response categories	Obs.	Mean	Std. dev.	Min	Max
Expected inflation rate over the next one year	Category [-5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5] Year over year change, %	29,197	0.95	1.48	-5	5
Expected expenditure changes over the next one year	Category [-10, -8, -6, -4, -2, 0, 2, 4, 6, 8, 10] Year over year change, %	40,340	0.79	4.53	-10	10
Expected income changes over the next one year	Category [-10, -8, -6, -4, -2, 0, 2, 4, 6, 8, 10] Year over year change, %	37,343	-1.03	3.93	-10	10
Income change compared with one year ago	Category [-10, -8, -6, -4, -2, 0, 2, 4, 6, 8, 10] Year over year change, %	38,698	-1.07	4.18	-10	10
Items used for constructing dummy variables:						
Household income before tax and with bonuses	Category [1.0, 1.5, 3.0, 5.0, 7.0, 9.0, 11, 13, 15, 17, 19, 21] Mil. yen	37,866	6.53	4.08	1	21
Number of household members	Number	43,153	3.49	1.47	1	12
Financial assets (savings, stocks, bonds, insurance policies, etc.)	Category [1, 2] (1 for less than 2.5 million yen, 2 for 2.5 million yen and over)	35,048	1.26	0.44	1	2
Planning large expenditures in the near future	Category [1, 2, 3, 4, 5] (From 1 for "Doesn't hold true at all for me" to 5 for "Particularly true for me")	42,090	2.81	1.26	1	5
Gender	Category [1, 2] (1: Male, 2: Female)	43,665	1.53	0.50	1	2
Age	Category [1, 2, 3, 4, 5] (1: 20-29, 2: 30-39, 3: 40-49, 4: 50-59, 5: over 60)	43,663	3.61	1.25	1	5
Education	Category [1, 2, 3] (1: Graduated from elementary/junior high school, 2: Graduated from high school or professional/technical school, 3: Graduated from college including associate's degree (2 year))	42,784	2.26	0.66	1	3

Note: Age and educational attainment were consolidated into the five and three groups shown here by the authors.

Table 2. Estimation results for the Euler equation

Dependent variable: Real spending one year from now						
Explanatory variables	(1)	(2)	(3)	(4)	(5)	(6)
Inflation expectations	-0.079***	-0.159***	-0.200***	-0.241***	-0.124***	-0.204***
(1 year from now)	(0.025)	(0.030)	(0.050)	(0.045)	(0.030)	(0.036)
× Income per household member			0.122**	0.096*		
(1.5-3.0 million yen)			(0.058)	(0.052)		
× Income per household member			0.181***	0.112**		
(Less than 1.5 million yen)			(0.062)	(0.057)		
× Few financial assets					0.125**	0.129**
					(0.049)	(0.056)
Real income one year from now	0.167***	0.172***	0.164***	0.171***	0.166***	0.172***
	(0.010)	(0.012)	(0.010)	(0.008)	(0.010)	(0.012)
Income compared with one year ago	0.092***	0.093***	0.097***	0.093***	0.098***	0.097***
	(0.009)	(0.010)	(0.009)	(0.008)	(0.009)	(0.010)
Income per household member			0.163*	-0.123		
(1.5-3.0 million yen)			(0.085)	(0.118)		
Income per household member			0.406***	-0.077		
(Less than 1.5 million yen)			(0.092)	(0.146)		
Few financial assets					-0.032	-0.141
					(0.073)	(0.116)
Planning large expenditures or purchases	0.801***	0.631***	0.805***	0.628***	0.780***	0.596***
in the future	(0.059)	(0.075)	(0.059)	(0.072)	(0.061)	(0.078)
Constant	0.210**	0.326***	0.007	0.406***	0.226**	0.386***
	(0.082)	(0.113)	(0.102)	(0.146)	(0.090)	(0.123)
Estimation period	From 2004 to 2013					
Observations	27,911	27,911	27,861	27,861	25,918	25,918
Number of households	7,472	7,472	7,467	7,467	7,077	7,077
Household fixed effect	No	Yes	No	Yes	No	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes

Notes: 1. Robust standard errors in parentheses. ***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively.
2. Income per household member is calculated as (household income / number of household members).
3. For income groups, the omitted category is 3.0 millon yen and over.
4. The dummy for planning large expenditures or purchases in the future takes 1 for those who responded this was "particularly true" or "somewhat true" and 0 for other responses.
5. "Few financial assets" represents households with financial assets (savings, stocks, insurance policies, etc.) of less than 2.5 million yen.
6. We omit households that purchased a house (or apartment) in the previous year or whose ratio of spending on durable goods to income is in the top 1% of the sample to exclude the temporary increase in spending compared with one year ago and the expected decline in the next year.

Table 3. Estimation results of the ordered probit model: Inflation perceptions and expectations

Dependent variable: Inflation expectations								
Explanatory variables	(1) 1 year	Marginal effect	(2) 5 year	Marginal effect	(3) 1 year	Marginal effect	(4) 5 year	Marginal effect
Perceived price changes compared with one year ago	0.587***	9.43	0.334***	10.92	0.588***	9.43	0.342***	10.94
	(0.012)		(0.012)		(0.011)		(0.012)	
× Income per household member (1.5-3.0 million yen)	-0.002	0.34	0.022	0.67	-0.003	0.34	0.020	0.62
	(0.015)		(0.014)		(0.013)		(0.014)	
× Income per household member (Less than 1.5 million yen)	0.033**	1.53	0.051***	1.68	0.033***	1.54	0.049***	1.62
	(0.014)		(0.013)		(0.012)		(0.013)	
× High financial literacy					-0.005	0.17	-0.048***	-1.24
					(0.013)		(0.014)	
Income per household member (1.5-3.0 million yen)	0.040***	0.55	-0.010	0.25	0.041***	0.57	-0.008	0.27
	(0.013)		(0.013)		(0.013)		(0.013)	
Income per household member (Less than 1.5 million yen)	0.072***	1.66	-0.003	1.17	0.073***	1.68	-0.000	1.19
	(0.013)		(0.012)		(0.013)		(0.012)	
High financial literacy					0.030**	0.38	0.055***	0.46
					(0.014)		(0.014)	
Female	0.003	0.05	-0.030***	-0.88	0.005	0.07	-0.028***	-0.83
	(0.008)		(0.008)		(0.008)		(0.008)	
Age 30-39	-0.038***	-0.54	0.054***	1.56	-0.037***	-0.54	0.054***	1.57
	(0.015)		(0.015)		(0.014)		(0.015)	
Age 40-49	-0.023	-0.33	0.026*	0.74	-0.023	-0.33	0.026*	0.76
	(0.015)		(0.015)		(0.014)		(0.015)	
Age 50-59	0.055***	0.83	0.076***	2.21	0.055***	0.83	0.076***	2.22
	(0.014)		(0.014)		(0.014)		(0.014)	
Age 60-69	0.160***	2.56	0.134***	3.99	0.159***	2.55	0.134***	3.98
	(0.015)		(0.014)		(0.014)		(0.015)	
Age 70+	0.128***	2.02	0.058***	1.67	0.128***	2.01	0.057***	1.65
	(0.016)		(0.015)		(0.015)		(0.015)	
Working in agriculture, forestry, or fisheries	-0.087***	-1.32	-0.127***	-3.66	-0.087***	-1.32	-0.127***	-3.66
	(0.025)		(0.024)		(0.025)		(0.024)	
Self-employed, working for a family business, of professional worker	-0.084***	-1.28	-0.062***	-1.82	-0.083***	-1.27	-0.061***	-1.80
	(0.014)		(0.013)		(0.013)		(0.013)	
Non-regular employee (part-timer)	-0.010	-0.15	-0.003	-0.08	-0.010	-0.15	-0.003	-0.08
	(0.012)		(0.012)		(0.012)		(0.012)	
Other	-0.035***	-0.55	-0.030***	-0.88	-0.036***	-0.57	-0.031***	-0.91
	(0.011)		(0.010)		(0.011)		(0.010)	
Estimation period	From Sept. 2006 survey to Sept. 2018 survey							
Observations	104,342		103,144		104,342		103,144	
Year dummies	YES		YES		YES		YES	

Notes: 1. Robust standard errors in parentheses. ***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively.

2. The marginal effect represents the change in the probability (in %) that a household chooses "Price levels will go up significantly" for a one-unit increase in a variable, while holding all other variables at their mean.

3. The omitted categories for the dummy variables are as follows: (a) income per household member: 3.0 million yen and over, (b) gender: male, (c) age: under 29, (d) work status: regular employee.

4. The calculation of income per household member is described in the main text.

5. "High financial literacy" represents those who, in the question about the reasons behind their assessment of economic conditions, answered "economic indicators and statistics."

Table 4. Estimation results of the ordered probit model: Household characteristics and awareness of the Bank of Japan's policies

Dependent variable:	(1)		(2)		(3)		(4)		(5)		(6)		(7)		(8)	
	Price stability target of 2 percent				Price stability				Interest in BOJ's activities				BOJ's relationship to our lives			
Explanatory variables		Marginal effect		Marginal effect		Marginal effect		Marginal effect		Marginal effect		Marginal effect		Marginal effect		Marginal effect
Income per household member (1.5-3.0 million yen)	-0.281***	-9.21	-0.268***	-8.65	-0.244***	-8.68	-0.232***	-8.18	-0.169***	-2.00	-0.152***	-1.73	-0.153***	-5.91	-0.144***	-5.53
	(0.018)		(0.018)		(0.015)		(0.015)		(0.013)		(0.013)		(0.013)		(0.013)	
Income per household member (Less than 1.5 million yen)	-0.456***	-14.38	-0.435***	-13.53	-0.469***	-16.04	-0.451***	-15.28	-0.294***	-3.19	-0.268***	-2.82	-0.293***	-11.03	-0.279***	-10.47
	(0.017)		(0.017)		(0.014)		(0.014)		(0.013)		(0.013)		(0.013)		(0.013)	
High financial literacy			0.536***	17.57			0.383***	13.19			0.497***	6.29			0.263***	10.01
			(0.021)				(0.015)				(0.014)				(0.014)	
Female	-0.617***	-19.14	-0.593***	-18.15	-0.355***	-11.82	-0.334***	-11.04	-0.241***	-2.39	-0.212***	-2.06	-0.050***	-1.83	-0.033***	-1.23
	(0.012)		(0.012)		(0.010)		(0.010)		(0.010)		(0.009)		(0.010)		(0.010)	
Age 30-39	0.139***	2.99	0.152***	3.22	0.090***	2.43	0.095***	2.59	0.107***	0.63	0.116***	0.67	-0.073***	-2.71	-0.069***	-2.56
	(0.026)		(0.026)		(0.020)		(0.020)		(0.017)		(0.017)		(0.017)		(0.018)	
Age 40-49	0.363***	8.64	0.378***	8.89	0.318***	9.40	0.326***	9.57	0.241***	1.58	0.251***	1.63	-0.081***	-2.99	-0.077***	-2.85
	(0.024)		(0.024)		(0.020)		(0.020)		(0.017)		(0.017)		(0.017)		(0.017)	
Age 50-59	0.581***	15.07	0.593***	15.18	0.483***	14.95	0.488***	15.00	0.358***	2.60	0.365***	2.61	-0.062***	-2.29	-0.060***	-2.23
	(0.025)		(0.025)		(0.019)		(0.019)		(0.017)		(0.017)		(0.017)		(0.017)	
Age 60-69	0.869***	24.73	0.875***	24.51	0.606***	19.31	0.604***	19.06	0.571***	5.00	0.569***	4.86	-0.002	-0.07	-0.006	-0.24
	(0.024)		(0.024)		(0.019)		(0.019)		(0.017)		(0.017)		(0.017)		(0.017)	
Age 70+	0.954***	27.77	0.954***	27.30	0.550***	17.30	0.547***	17.04	0.677***	6.48	0.675***	6.30	-0.061***	-2.25	-0.066***	-2.43
	(0.025)		(0.025)		(0.020)		(0.020)		(0.019)		(0.019)		(0.019)		(0.019)	
Working in agriculture, forestry, or fisheries	-0.045	-1.32	-0.041	-1.22	-0.162***	-5.25	-0.165***	-5.31	0.015	0.15	0.015	0.15	-0.009	-0.32	-0.010	-0.35
	(0.040)		(0.040)		(0.029)		(0.029)		(0.029)		(0.029)		(0.029)		(0.029)	
Self-employed, working for a family business, or professional	0.066***	2.01	0.075***	2.26	-0.041**	-1.38	-0.035**	-1.17	0.080***	0.84	0.090***	0.94	0.055***	2.03	0.059***	2.20
	(0.022)		(0.022)		(0.017)		(0.017)		(0.016)		(0.016)		(0.017)		(0.017)	
Non-regular employee (part-timer)	-0.125***	-3.63	-0.128***	-3.67	-0.187***	-6.03	-0.189***	-6.06	-0.102***	-0.94	-0.105***	-0.95	-0.066***	-2.40	-0.067***	-2.42
	(0.018)		(0.018)		(0.015)		(0.015)		(0.014)		(0.014)		(0.014)		(0.014)	
Other	0.087***	2.68	0.069***	2.10	-0.017	-0.57	-0.034**	-1.14	0.021*	0.21	-0.002	-0.02	0.055***	2.05	0.044***	1.62
	(0.017)		(0.017)		(0.014)		(0.014)		(0.013)		(0.013)		(0.013)		(0.013)	
Estimation period	From Sept. 2013 survey to Sept. 2018 survey				From Sept. 2006 survey to Sept. 2018 survey											
Observations	42,568		42,568		62,700		62,700		62,648		62,648		62,658		62,658	
Year dummies	YES		YES		YES		YES		YES		YES		YES		YES	

Notes: 1. Robust standard errors in parentheses. ***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively.

2. The question regarding the "Price stability target of 2 percent" is: "Do you know that the Bank has set the price stability target at 2 percent in terms of the year-on-year rate of change in the consumer price index (CPI)?" The question regarding "Price stability" is: "Do you know that one of the Bank's objectives is to achieve price stability?" The dependent variables for these questions are defined as follows: "Have never heard of it"=1, "Have read or heard of it, but do not know much about it"=2, "Know about it"=3.

3. The question regarding "Interest in the BOJ's activities" is: "How would you describe your level of interest in the Bank's activities?" In the estimation, the dependent variable is as follows: "Not interested" = 1, "Not particularly interested" = 2, "Difficult to say" = 3, "Somewhat interested" = 4, "Interested" = 5.

4. The question regarding "the BOJ's relationship to our lives" is: "How would you describe the Bank's relationship to our lives?" In the estimation, the dependent variable is as follows: "Not related" = 1, "Not particularly related" = 2, "Difficult to say" = 3, "Somewhat related" = 4, "Related" = 5.

5. The marginal effect represents the change in the probability (in %) that a household responds that it knows about the price stability target or the BOJ's objective, is interested in the BOJ's activities, or replies that the BOJ's activities are relevant to our lives for a one-unit increase in a variable while holding all other variables at their mean.

6. The omitted categories for the dummy variable are as follows: (a) income per household member: 3.0 million yen and over, (b) gender: male, (c) age: under 29, (d) work status: regular employee.

7. The calculation of income per household member is described in the main text.

8. "High financial literacy" represents those who, in the question about the reasons behind their assessment of economic conditions, answered "economic indicators and statistics."

Appendix Table 1. Estimation results of the ordered probit model: Inflation perceptions and expectations

Dependent variable: Inflation expectations								
Explanatory variables	(1) 1 year	Marginal effect	(2) 5 year	Marginal effect	(3) 1 year	Marginal effect	(4) 5 year	Marginal effect
Perceived price changes compared with one year ago	0.589***	9.79	0.351***	10.74	0.576***	9.43	0.322***	10.92
	(0.014)		(0.013)		(0.018)		(0.019)	
× Income per household member (1.5-3.0 million yen)	0.015	0.98	0.022	0.78				
	(0.017)		(0.017)					
× Income per household member (Less than 1.5 million yen)	0.054***	2.41	0.040**	1.42				
	(0.018)		(0.018)					
× Household income (5.0-10.0 million yen)					-0.004	0.48	0.030	1.05
					(0.019)		(0.020)	
× Household income (3.0-5.0 million yen)					0.019	1.39	0.048**	1.80
					(0.019)		(0.020)	
× Household income (Less than 3.0 million yen)					0.056***	2.57	0.074***	2.51
					(0.018)		(0.020)	
× High financial literacy	-0.026	-0.06	-0.048**	-1.05	-0.006	0.17	-0.048***	-1.18
	(0.020)		(0.020)		(0.013)		(0.014)	
Income per household member (1.5-3.0 million yen)	0.062***	1.21	0.009	0.79				
	(0.018)		(0.018)					
Income per household member (Less than 1.5 million yen)	0.102***	2.59	0.014	1.37				
	(0.020)		(0.020)					
Household income (5.0-10.0 million yen)					0.059***	0.77	0.012	1.07
					(0.019)		(0.018)	
Household income (3.0-5.0 million yen)					0.097***	1.72	0.031*	2.07
					(0.019)		(0.018)	
Household income (Less than 3.0 million yen)					0.122***	2.77	0.012	2.14
					(0.018)		(0.018)	
High financial literacy	0.057***	0.47	0.080***	1.25	0.032**	0.39	0.056***	0.51
	(0.021)		(0.021)		(0.014)		(0.014)	
Female	0.020	0.32	-0.044***	-1.31	0.005	0.08	-0.028***	-0.83
	(0.012)		(0.012)		(0.008)		(0.008)	
Age 30-39	0.004	0.06	0.114***	3.21	-0.016	-0.24	0.058***	1.67
	(0.027)		(0.026)		(0.014)		(0.015)	
Age 40-49	0.048*	0.69	0.107***	3.02	0.006	0.08	0.033**	0.94
	(0.028)		(0.027)		(0.014)		(0.015)	
Age 50-59	0.109***	1.62	0.140***	3.99	0.079***	1.20	0.083***	2.41
	(0.026)		(0.025)		(0.014)		(0.015)	
Age 60-69	0.198***	3.11	0.172***	4.95	0.168***	2.66	0.135***	4.00
	(0.025)		(0.024)		(0.014)		(0.015)	
Age 70+	0.158***	2.43	0.097***	2.72	0.128***	1.98	0.053***	1.54
	(0.026)		(0.025)		(0.015)		(0.015)	
Working in agriculture, forestry, or fisheries	-0.099**	-1.57	-0.167***	-4.72	-0.081***	-1.25	-0.124***	-3.59
	(0.047)		(0.046)		(0.025)		(0.024)	
Self-employed, working for a family business, of professional worker	-0.094***	-1.50	-0.095***	-2.74	-0.084***	-1.29	-0.059***	-1.75
	(0.022)		(0.022)		(0.013)		(0.013)	
Non-regular employee (part-timer)	-0.025	-0.40	0.018	0.53	-0.018	-0.28	-0.003	-0.09
	(0.022)		(0.021)		(0.012)		(0.012)	
Other	-0.046**	-0.74	-0.029	-0.86	-0.042***	-0.66	-0.031***	-0.91
	(0.019)		(0.019)		(0.011)		(0.010)	
Estimation period	From Sept. 2006 survey to Sept. 2018 survey							
Observations	38,756		38,225		104,618		103,411	
Year dummies	YES		YES		YES		YES	

Notes: 1. Robust standard errors in parentheses. ***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively.

2. Columns (1) and (2) are the results when the sample is restricted to households for which the number of members is obvious. Columns (3) and (4) show the results when we do not use the data for the number of household members and classify income based on the total household income.

3. The omitted categories for the dummy variables are as follows: (a) income per household member: 3.0 million yen and over, (b) household income: 10 million yen and over, (c) gender: male, (d) age: under 29, (e) work status: regular employee.

4. "High financial literacy" represents those who, in the question about the reasons behind their assessment of economic conditions, answered "economic indicators and statistics."

5. The marginal effect represents the change in the probability (in %) that a household chooses "Price levels will go up significantly" for a one-unit increase in a variable while holding all other variables at their mean.

Appendix Table 2. Estimation results of the ordered probit model: Household characteristics and awareness of the Bank of Japan's policies

Dependent Variable:	(1)		(2)		(3)		(4)		(5)		(6)		(7)		(8)	
	Price Stability target at 2 percent				Price Stability				Interest in BOJ's activities				BOJ's relationship to our lives			
Explanatory variables		Marginal effect		Marginal effect		Marginal effect		Marginal effect		Marginal effect		Marginal effect		Marginal effect		Marginal effect
Household income	-0.362***	-12.32	-0.337***	-11.30	-0.306***	-11.16	-0.292***	-10.54	-0.220***	-2.96	-0.199***	-2.54	-0.184***	-7.21	-0.172***	-6.72
(5.0-10.0 million yen)	(0.026)		(0.026)		(0.022)		(0.022)		(0.019)		(0.019)		(0.020)		(0.020)	
Household income	-0.542***	-17.96	-0.511***	-16.66	-0.512***	-18.25	-0.489***	-17.30	-0.318***	-4.02	-0.285***	-3.46	-0.321***	-12.41	-0.304***	-11.68
(3.0-5.0 million yen)	(0.026)		(0.026)		(0.022)		(0.022)		(0.019)		(0.019)		(0.020)		(0.020)	
Household income	-0.699***	-22.47	-0.667***	-21.09	-0.716***	-24.69	-0.691***	-23.62	-0.449***	-5.21	-0.412***	-4.61	-0.435***	-16.53	-0.416***	-15.72
(Less than 3.0 million yen)	(0.027)		(0.027)		(0.022)		(0.022)		(0.019)		(0.019)		(0.020)		(0.020)	
High financial literacy			0.534***	17.48			0.379***	13.00			0.495***	6.26			0.262***	9.96
			(0.021)				(0.015)				(0.014)				(0.014)	
Female	-0.617***	-19.10	-0.592***	-18.11	-0.357***	-11.82	-0.336***	-11.05	-0.241***	-2.39	-0.213***	-2.07	-0.049***	-1.82	-0.033***	-1.23
	(0.012)		(0.012)		(0.010)		(0.010)		(0.009)		(0.009)		(0.010)		(0.010)	
Age 30-39	0.067***	1.46	0.081***	1.73	0.009	0.24	0.017	0.46	0.062***	0.37	0.073***	0.43	-0.119***	-4.43	-0.114***	-4.23
	(0.026)		(0.026)		(0.020)		(0.020)		(0.018)		(0.018)		(0.018)		(0.018)	
Age 40-49	0.267***	6.34	0.284***	6.67	0.206***	6.04	0.216***	6.32	0.177***	1.16	0.191***	1.24	-0.148***	-5.48	-0.143***	-5.25
	(0.025)		(0.025)		(0.020)		(0.020)		(0.018)		(0.018)		(0.018)		(0.018)	
Age 50-59	0.495***	12.89	0.510***	13.08	0.393***	12.19	0.401***	12.33	0.306***	2.25	0.316***	2.28	-0.116***	-4.29	-0.113***	-4.17
	(0.025)		(0.025)		(0.020)		(0.020)		(0.017)		(0.017)		(0.018)		(0.018)	
Age 60-69	0.840***	24.38	0.846***	24.16	0.577***	18.65	0.576***	18.43	0.554***	5.02	0.552***	4.87	-0.019	-0.71	-0.023	-0.86
	(0.024)		(0.024)		(0.019)		(0.019)		(0.017)		(0.017)		(0.017)		(0.017)	
Age 70+	0.951***	28.36	0.951***	27.87	0.551***	17.70	0.548***	17.44	0.675***	6.77	0.674***	6.56	-0.061***	-2.29	-0.066***	-2.47
	(0.025)		(0.025)		(0.020)		(0.020)		(0.019)		(0.019)		(0.019)		(0.019)	
Working in agriculture, forestry, or	-0.074*	-2.17	-0.068*	-1.98	-0.187***	-5.96	-0.188***	-5.98	-0.001	-0.01	0.002	0.02	-0.024	-0.89	-0.024	-0.87
fisheries	(0.040)		(0.040)		(0.029)		(0.029)		(0.029)		(0.029)		(0.029)		(0.029)	
Self-employed, working for a	0.067***	2.05	0.077***	2.32	-0.039**	-1.27	-0.032*	-1.06	0.080***	0.83	0.091***	0.94	0.056***	2.06	0.061***	2.24
family business, of professional	(0.022)		(0.022)		(0.017)		(0.017)		(0.016)		(0.016)		(0.017)		(0.017)	
Non-regular employee	-0.108***	-3.12	-0.110***	-3.15	-0.162***	-5.20	-0.164***	-5.24	-0.089***	-0.81	-0.091***	-0.83	-0.052***	-1.88	-0.053***	-1.90
(part-timer)	(0.018)		(0.018)		(0.015)		(0.015)		(0.014)		(0.014)		(0.014)		(0.014)	
Other	0.096***	2.95	0.080***	2.40	-0.003	-0.11	-0.020	-0.66	0.028**	0.28	0.006	0.06	0.063***	2.34	0.052***	1.92
	(0.017)		(0.017)		(0.014)		(0.014)		(0.013)		(0.013)		(0.013)		(0.013)	
Estimation period	From Sept. 2013 survey to Sept. 2018 survey				From Sept. 2006 survey to Sept. 2018 survey											
Observations	42,679		42,679		62,857		62,857		62,799		62,799		62,806		62,806	
Year dummies	YES		YES		YES		YES		YES		YES		YES		YES	

Notes: 1. Robust standard errors in parentheses. ***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively.

2. The question regarding the "Price stability target of 2 percent" is: "Do you know that the Bank has set the price stability target at 2 percent in terms of the year-on-year rate of change in the consumer price index (CPI)?" The question regarding "Price stability" is: "Do you know that one of the Bank's objectives is to achieve price stability?" The dependent variables for these questions are defined as follows: "Have never heard of it"=1, "Have read or heard of it, but do not know much about it"=2, "Know about it"=3.

3. The question regarding "Interest in the BOJ's activities" is: "How would you describe your level of interest in the Bank's activities?" In the estimation, the dependent variable is as follows: "Not interested" = 1, "Not particularly interested" = 2, "Difficult to say" = 3, "Somewhat interested" = 4, "Interested" = 5.

4. The question regarding "the BOJ's relationship to our lives" is: "How would you describe the Bank's relationship to our lives?" In the estimation, the dependent variable is as follows: "Not related" = 1, "Not particularly related" = 2, "Difficult to say" = 3, "Somewhat related" = 4, "Related" = 5.

5. The marginal effect represents the change in the probability (in %) that a household responds that it knows about the price stability target or the BOJ's objective, is interested in the BOJ's activities, or replies that the BOJ's activities are relevant to our lives for a one-unit increase in a variable while holding all other variables at their mean.

6. The omitted categories for the dummy variable are as follows: (a) household income: 10.0 million yen and over, (b) gender: male, (c) age: under 29, (d) work status: regular employee.

7. "High financial literacy" represents those who, in the question about the reasons behind their assessment of economic conditions, answered "economic indicators and statistics."