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Estimation of firms' inflation expectations using the survey DI

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Abstract

This study uses the Bank of Japan's *Tankan* (Short-Term Economic Survey of Enterprises in Japan) data to estimate the long-run time series of Japanese firms' inflation expectations since 1990. In the Tankan, the series for "consumer price inflation expectations" and "output price inflation expectations" go back to 2014, while that for "output price DI" features a longer time series. Using the relationship between these series for 2014–2022, we estimate the one-year ahead consumer price inflation expectations for 1990–2013 based on the output price DI. The firms' inflation expectations obtained are found to have information that improves forecast accuracy when forecasting consumer price inflation, which is not included in the lag in inflation or the output gap, and enhances forecast accuracy more than economists' inflation expectations.

JEL classification: C22, E31, E37
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1. Introduction

In macroeconomics, inflation expectations are closely linked to economic activity, and are essential for empirical analyses. However, fewer candidate inflation expectations data are available for empirical analysis than other economic variables. In particular, when the analysis covers a long period, time-series data on inflation expectations are often difficult to trace long into the past, considerably limiting the candidate data used in the empirical analysis.

Inflation expectations data can be categorized according to the forecast entity (e.g., Adachi and Hiraki, 2021). Data on economists, households, and firms' expectations rely on survey research. In Japan, the "ESP Forecast" for economists, the Bank of Japan's "Opinion Survey on the General Public's Views and Behavior" for households, and the "Tankan" (Short-Term Economic Survey of Enterprises in Japan) for firms include questions concerning inflation expectations.

Inflation expectations can vary depending on an entity's expectations. Coibion, Gorodnichenko, and Kamdar (2018) and Coibion, Gorodnichenko, and Kumar (2018) show that firms' inflation expectations differ significantly from those of other entities regarding time series dynamics and determining factors. Furthermore, as firms are price setters, their inflation expectations are particularly important in macroeconomic empirical analyses.

Nevertheless, no long-run time-series data exist on firms' inflation expectations in Japan. The Tankan can only be traced back to 2014 when the survey began asking questions on inflation expectations. The inflation expectations data that can be consistently traced back to the past the most are contained in the Cabinet Office's "Annual Survey of Corporate Behavior," only going back to 2003.[1] This survey is conducted annually. This lack of long-run time series data on firms' inflation expectations is a problem faced by researchers in Japan and other countries, as Coibion et al. (2020) point out.

The output price diffusion index (DI) in the Tankan is often used as a proxy variable to analyze Japanese firms' inflation expectations. The output price DI includes queries of "actual" (current) and "future" prices. As the "future" figure is the response concerning changes to the firm's output prices from the present to three months ahead, it can be regarded as an indicator of expected price changes up to three months ahead. Long-run time series since the 1970s are available as an average series for all industries and sizes. Series by industry and size are also maintained.

[1] The survey does not directly ask about inflation expectations but investigates expectations for nominal and real GDP growth rates: the difference between the two is interpreted as expected inflation and used for analysis. See Appendix 2 of this study and Kaihatsu and Shiraki (2016) for details.

This study generates long-run time series data on Japanese firms' inflation expectations for one year ahead. Specifically, we develop a framework for estimating one-year-ahead inflation expectations using the Tankan output price DI, for which long-run time series data exist. The firms' inflation expectations are based on "outlook for general price inflation expectations (all industries and all sizes)" in the Tankan. Conceptually, this series can be interpreted as the average of all industries and sizes of each firm's inflation expectations.

The Tankan began surveying the outlook for consumer price inflation (hereafter, "CPI inflation expectations") and the outlook for the expected changes in the firm's output prices ("output price inflation expectations") as of the March 2014 survey. This study develops a framework for estimating one-year ahead CPI inflation expectations from output price DI using data from March 2014 to December 2022 surveys. As the output price DI is available for an extended period, even before 2014, it has been used to estimate CPI inflation expectations before 2014. Unless otherwise noted, in this study, the CPI and output price inflation expectations refer to expectations one year ahead.

An essential and unique aspect of this analysis is the use of data from Tankan on each firm's industry and size. The Tankan includes about 30 industry categories. There are three size categories: large, medium-sized, and small enterprises. Uno et al. (2018) show that a series averaging three consumer-related industries ("retailing," "services for individual," and "accommodations, eating & drinking services") for industry-specific output price inflation expectations draws close to the CPI inflation expectations. As the Tankan includes various manufacturing and non-manufacturing industries, the output price expectations for all industries and sizes include the prices of goods and services sold to both trading partners and consumers. By only aggregating consumer-related industries, we obtain a series close to the movement of CPI inflation expectations. The study focuses on the consumer-related industries.

We consider three ways to estimate CPI inflation expectations based on the output price DI by industry and size. The first regresses CPI inflation expectations on output price DI to obtain their relationship. The second method additionally uses output price inflation expectations by regressing each series of output price inflation expectations by industry and size on the output price DI for the same industry and size and then regressing CPI inflation expectations for all sizes and industries on a set of output price inflation expectations series. In the third method, instead of estimating an equation relating CPI inflation expectations to output price inflation expectations, as in the second method, we use the weight of individual items and services in the CPI. The estimated CPI inflation expectations are the weighted averages of the estimated output price inflation expectations of each industry sector based on this weight. Fixing the weights can result in a robust estimation framework.

A caveat of the estimation framework proposed in this paper is the use of a relatively short-term relationship for the period 2014–2022 to estimate historical long-run inflation expectations. The historical period assumes that the relationship between the series concerning inflation expectations is the same and constant as during 2014–2022. However, firm views on prices may change over time. Moreover, because inflation dynamics may have changed from the 1990s to the 2020s, the resulting estimates of inflation expectations estimates should be viewed within a reasonable range.

Regarding whether the estimates of inflation expectations going back in time are "correct," it is impossible to rigorously verify whether they are an appropriate series because the true figures for inflation expectations are unknown. Furthermore, as noted earlier, comparisons are impossible because Japanese firms have no other long-run time series of inflation expectations. Instead, this study includes the long-run time series of estimated inflation expectations into a forecasting model of CPI inflation rates to test whether it contains information on future inflation rates that other macroeconomic variables, such as foreign exchange rates and the output gap, cannot explain.[2]

Additionally, we conduct a comparative analysis of the differences between estimated firms' inflation expectations and economists' inflation expectations. Coibion et al. (2020) show that firms' inflation expectations in the U.S. and New Zealand differ from those of economists. To the best of our knowledge, no study has analyzed these factors for Japan over a sufficiently long period, mainly because it is impossible to obtain a long-run time series of firms' inflation expectations is impossible. Therefore, this study compares the Consensus Forecast's one-year-ahead inflation expectations obtained from Consensus Economic Inc. as economists' inflation forecasts to the estimated firms' inflation expectations.

This study's first contribution to the literature is that it presents long-run time-series data on firms' inflation expectations in Japan. To a certain extent, the proposed estimation method is adapted to a data structure specific to Tankan. However, this strategy contributes a new methodology to address the lack of data on firms' inflation expectations in other countries, as Coibion et al. (2020) highlighted.

Second, it provides empirical evidence on firms’ inflation expectations. The related literature on the characteristics of firms' and other entities’ inflation expectations in Japan includes Nishiguchi et al. (2014), Kamada et al. (2015), Hori and Kawagoe (2015),

[2] Hajdini et al. (2022) use a survey to estimate U.S. consumers' inflation expectations. As they do not know the true value of expected inflation, they conduct a quantitative analysis of the estimates obtained, such as their relationship to macroeconomic variables, including the actual inflation rate.

Nakazono (2016), Uno et al. (2018), Hogen and Okuma (2018), Inatsugu et al. (2019), Kitamura and Tanaka (2019), Maruyama and Suganuma (2019), Hiraki and Hirata (2020), Kikuchi and Nakazono (2021), and Nakajima et al. (2021).

The remainder of this paper is organized as follows. Section 2 provides a detailed description of the Tankan series used in out estimation. Section 3 describes the framework for estimating firms' inflation expectations and presents the estimation results. Section 4 analyzes the time series property and predictive power of the estimated firms' inflation expectations. Finally, Section 5 concludes.

2. Tankan index of inflation expectations

2-1. Available series

The Tankan is a survey of actual corporate activities in Japan that has a long history, with its predecessor surveys dating back to the 1950s. The current "Short-Term Economic Survey of Enterprises in Japan" was launched in 1974, and data from that time are available for download on the Bank's website. The survey reviews the companies and items surveyed to reflect the economic structure and corporate-sector developments. Some items have only been surveyed at certain times in the past or relatively recently. The survey is conducted four times a year (March, June, September, and December) and is generally used as quarterly data.

Regarding the series on inflation expectations, the items "Outlook of Output Prices" and "Outlook of General Prices (i.e., CPI)" were launched in 2014. The former question asks about the companies' outlook for the sales price of their main products or the price of their main service offerings one, three, and five years from now, compared to the current level. The latter asks for one-, three-, and five-year outlooks concerning year-on-year changes in the CPI. Responses are based on a multiple-choice format, with expectations in 5% bands (e.g., "around +10%" indicates the range from +7.5% to +12.4%) for the output price expectations and 1% bands ("around +2% referes to the range from +1.5% to +2.4%) for the CPI inflation expectations (see Appendix A for details). The "Average of Enterprises' Inflation Outlook" is included as a reference value, a weighted average of the values for each option (e.g., +2% for "+2% or so" and +6% for "+6% or more") weighted by the percentage of the number of companies for each option. While still a reference value, we generally refer to this average outlook when we deal with Tankan's inflation expectations.

Meanwhile, one of Tankan's DI items is the "Changes in Output Prices," with the three options being "rise," "unchanged," or "fall." The output price DI, calculated by subtracting the "fall" percentage from the "rise" percentage, is used in various analyses as a series close to the concept of inflation expectations.[3] One advantage of using this DI is the availability of long-run time series from 1974 for all firm sizes and industries.

This study estimates the long-run time series for the one-year-ahead CPI inflation expectations. The output price DI, for which a long-run time series is available, is used for this purpose. The DI includes "actual" (current) and "future," with the "future" item asking about changes in the next three months. We include one-year ahead CPI inflation expectations in our analysis because changes up to three months ahead are expected to contain information about changes up to one year ahead.

In principle, it is possible to consider an estimation framework for CPI inflation expectations for three or five years ahead. However, the greater the number of years of expectations, the less affinity they have with output price decisions and the less accurate the estimation. For a one-year forecast, the DI movements generated from the responses to recent developments are likely to contain considerable information, given that shocks related to recent price changes will have a proportional impact on the inflation rate one year ahead through inertia. Nevertheless, when the forecast is more than three years ahead, the correlation with DI is lower because recent shocks decay over time. Therefore, inflation expectations for three and five years ahead are beyond the scope of the main analysis. Appendix B tries to estimate medium- and long-term inflation expectations by additionally using the "Annual Survey of Corporate Behavior."

2-2. Overview of inflation expectations in Tankan

Figure 1 shows one-year ahead CPI inflation expectations and output price expectations for all firm sizes and industries.[4] The one-year ahead CPI inflation expectations declined from approximately 1.5% in 2014, when the survey began, to a low 0% range in 2015–2016, remained at the same level, and further declined in late 2019. The variable began to rise in 2021 and rose significantly to over 2% in 2022. The one-year ahead output price forecast moves similarly to the one-year ahead CPI inflation expectations but at different levels and ranges of change. In 2014, the decline was lower than the CPI inflation expectations at approximately 1%, larger than the 2019 decline. The increase in 2021–2022 was greater than the CPI inflation expectations. During this period, the output price DI moved like that of the expectations series.

Figure 2 plots one-year ahead CPI inflation expectations for all firm sizes and

[3] DI calculated from selective (categorical) responses to surveys are often used in macroeconomic empirical analyses because they have a high correlation with a range of economic variables (see Pinto et al., 2020).

[4] The Tankan price outlook excludes the effects of consumption tax hikes and other systemic changes.

industries versus one-year ahead output price expectations for consumer-related industries. For consumer-related industries, the figures for the three industries are weighted and averaged by their weight in the CPI. Specifically, for the retailing, services for individuals, and "accommodations, eating & drinking services," we use the weighted average of the weights in the 2020-based CPI for goods (weight: 0.5046), services excluding accommodation and food services (0.4414), and accommodation and food services (0.0540). Uno et al. (2018) note that the average CPI inflation expectations for firms aggregated across all industries and all sizes are close to this consumer-related industry output price expectations. We focus on these consumer-related industries when selecting variables for the following estimation.

3. Method for estimating inflation expectations

3-1. Estimation formula 1: One-step direct regression

First, we consider the following regression equation to estimate the CPI inflation expectations for all sizes and industries from the output price DI series by industry and size:

$$y_t = c + \boldsymbol{x}_t \boldsymbol{b} + e_t, \quad t = 1, \dots, n,$$

where y_t is the CPI inflation expectations for all firm sizes and industries for survey t, $\boldsymbol{x}_t = (x_{1t}, \dots, x_{kt})$ is a vector of the selected k industry- and firm-size-specific output price DIs, and $\boldsymbol{b} = (b_1, \dots, b_k)'$ is the regression coefficient. Using $\hat{c}$ and $\widehat{\boldsymbol{b}}$, estimated using the least squares method, the CPI inflation expectations before 2013 are calculated as follows:

$$\hat{y}_t = \hat{c} + \boldsymbol{x}_t \widehat{\boldsymbol{b}}.$$

If the number of selected series (k) included in $\boldsymbol{x}_t$ is larger than that of observations (n) in the estimation period, the least squares method cannot be used for the estimation. In this case, the LASSO regression method is used to estimate c and $\boldsymbol{b}$, which minimizes the following equation:

$$L = \sum_{t=1}^{n} (y_t - c - \boldsymbol{x}_t \boldsymbol{b})^2 + \lambda(|c| + \sum_{i=1}^{k} |b_i|).$$

For parameter λ, we use the optimal value based on cross-validation.

3-2. Estimation formula 2: Two-stage indirect regression

Next, we consider the additional use of the series of one-year-ahead output price expectations by firm industry and size for the estimation. Specifically, we implement the following two regression equations:

(Stage 1) $z_{it} = c_{1i} + x_{it}b_{1i} + \varepsilon_{it}, \quad i = 1, \dots, k; \ t = 1, \dots, n,$

(Stage 2) $y_t = c_2 + \boldsymbol{z}_t\boldsymbol{b}_2 + e_t, \quad t = 1, \dots, n,$

where z_{it} is the output price expectations by industry and size, and the vector of its collection is defined as $\boldsymbol{z}_t = (z_{1t}, \dots, z_{kt})$. We estimate the two equations separately using the least squares method, and these estimated values are $\hat{c}_{1i}$, $\hat{b}_{1i}$, $\hat{c}_2$, and $\hat{\boldsymbol{b}}_2$. Subsequently, we calculate CPI inflation expectations before 2013 using the following equation:

$$\hat{z}_{it} = \hat{c}_{1i} + x_{it}\hat{b}_{1i}, \quad i = 1, \dots, k,$$

$$\hat{y}_t = \hat{c}_2 + \hat{\boldsymbol{z}}_t\hat{\boldsymbol{b}}_2,$$

where $\hat{\boldsymbol{z}}_t = (\hat{z}_{1t}, \dots, \hat{z}_{kt})$. Similar to the one-step direct regression, if the number of selected series (k) is large, we estimate c_2 and $\boldsymbol{b}_2$ using the LASSO regression method in the second stage of the estimation.

Because the one-step direct regression has fewer parameter constraints than the two-step indirect regression, the average difference between the theoretical $(\hat{y}_t)$ and observed (y_t) values obtained from the estimation equation is smaller. However, the two-stage indirect regression is based on the relationship between x_{it} and z_{it}, in which the same firms respond by industry and size, is strong. If we apply this relationship to the data, the forecasting accuracy may be higher than that of the one-step direct regression.

3-3. Estimation formula 3: Two-stage weighted regression

We consider a method in which the second estimation equation in Estimation formula 2 is modified as follows:

(Stage 2) $y_t = c_3 + Z_t b_3 + e_t, \quad t = 1, \dots, n,$

where Z_t is the weighted average of $z_{1t}, \dots, z_{kt}$:

$$Z_t = \sum_{i=1}^{k} z_{it} w_i,$$

with w_i denoting the weighted average weight, and $\sum_{i=1}^{k} w_i = 1$. Specifically, we use the weights for individual prices in the CPI summed for individual prices corresponding to industry i, as w_i. For example, if we use two industries, retailing $(i = 1)$ and services for individuals $(i = 2)$, as explanatory variables, w_1 and w_2 are standardized so that the weights in the CPI of goods and services, excluding accommodation and food services, sum to one. We calculate CPI inflation expectations before 2013 as follows:

$$\hat{z}_{it} = \hat{c}_{1i} + x_{it}\hat{b}_{1i}, \quad i = 1, \dots, k,$$

$$\hat{Z}_t = \sum_{i=1}^{k} \hat{z}_{it} w_i,$$

$$\hat{y}_t = \hat{c}_3 + \hat{Z}_t \hat{b}_3.$$

Using a single weighted average explanatory variable $(z_{1t}, \dots, z_{kt})$ instead of multiple explanatory variables (Z_t) in the second stage may remove the effect of outliers in the short sample period for the second-stage estimation and may increase forecast accuracy compared with the Estimation formula 2.

The weights (w_i) are those of the 2020 base CPI relative to the individual prices. Although it is possible to use historical standards and vary the weights at different times, we apply the most recent standards uniformly throughout the sample period to create CPI inflation expectations that are consistent with the latest CPI inflation rates.

4. Empirical analysis

4-1. Candidate explanatory variables and selection criteria

We estimate each set of explanatory variables listed in Table 1 and explore the best variable set. These variables are classified into three categories. The first uses a single series, an all-firm-size series for all industries (Set 1), retailing only (Set 2), and a consumer-related industry average (Set 3). The second approach combines three consumer-related industry breakdowns using two or three series (Sets 4–6). The third approach uses individual industry series, testing industries of all sizes (Set 7) and industries by size (Set 8). As Sets 1–3 are single series sets, we apply two estimation formulae: (1) one-step direct regression and (2) two-step indirect regression. For Sets 4–6, we additionally examine (3) two-step weighted regression. For Sets 7 and 8, because evaluating the CPI weights tied to each industry sector is difficult, we only apply the first two formulae.

The output price DI for services for individuals, and "accommodations, eating & drinking services" can only be traced back to the June 2004 survey. Before 2004, there was an industry classification series called "Services," which could be traced back to the December 1990 survey. Therefore, those two series are, respectively, connected by subtracting the difference between the DI in June 2004 from the "Services" DI before March 2004.

As a criterion for choosing the best set of variables and estimation equations, we first examine the in-sample root-mean-squared error (RMSE) within the estimation period for the difference between $\hat{y}_t$, obtained from the estimation equations and the observed values. The estimation period spans 36 survey cycles from the March 2014 to December 2022.

Next, we compare out-of-sample predictability. We begin with estimates using the March 2014–December 2017 surveys samples. The resulting estimates forecast the CPI inflation expectations one period ahead—from the output price DI in the March 2018 survey to the CPI inflation expectations in the same survey. Next, we add March 2018 survey data and produce estimates, similarly projecting CPI inflation expectations one period ahead of the June 2018 survey data. This process is repeated until December 2022 survey forecast. We examine the RMSE for the difference between the forecast and actual observed values from the March 2018–December 2022 surveys. To confirm the robustness of the results, we also examine the RMSE changing the starting period of the forecast to 2019–2021.

4-2. Estimation results

Table 2 shows in-sample RMSEs for each candidate set of variables and estimation equations. As mentioned above, the in-sample RMSEs are smaller for all approaches because one-stage direct estimation is less parameter-constrained than two-stage indirect estimation. However, as the difference is at most 0.01, there can be almost no difference.

The RMSE is smaller when using the consumer industries in Sets 2–6 as explanatory variables than when Set 1, which features the series of all firm sizes and industries as the explanatory variable. The RMSEs for Sets 5 and 6, including retailing and "accommodations, eating & drinking services" are small. Sets 7 and 8, including non-consumer-related industries, have relatively large RMSEs, indicating that a simpler model focusing on consumer industries in Sets 2–6 is superior. Although Sets 7 and 8 are estimated using the LASSO regression method, and the series of several industries including consumption-related industries are statistically significant, the estimated coefficient for consumption-related industries shrink to some extent. Therefore, the in-sample fit deteriorates. Because in-sample fit is relevant in creating inflation expectations, Sets 7 and 8 are dropped from the following analyses.

Table 3 presents the RMSE of the out-of-sample predictability. As with the in-sample, the RMSE is smaller when considering the consumer-related industries in Sets 2–6 as explanatory variables than when using Set 1. In Sets 2 and 3, featuring only one explanatory variable, the one-stage direct estimation exibits a smaller RMSE than the two-stage indirect estimation. Conversely, in Sets 4–6, which feature multiple explanatory variables, the two-stage indirect estimation has a smaller RMSE. This result indicates that the supplemental use of data on output price expectations improves forecast accuracy more than using the output price DI alone.

Moreover, the out-of-sample RMSE is smaller for the two-stage weighted estimation than for the two-stage indirect estimation. This result suggests that a stable forecast can be produced by fixing each industry's weight to values consistent with the CPI. Among all variable sets and estimation equations, the two-stage weighted estimation in Set 6 has the smallest RMSE. This result is robust, even when the beginning of the forecast period changes. Thus, we employ the long-run time series of inflation expectations estimated using this method to conduct the following analysis.

Interestingly, the best results are obtained when using only consumer-related industries as a model for estimating inflation expectations for all industries and firm sizes. This result is reasonable, as these industries are the basis for the CPI. One may argue that additional information on upstream corporate prices during production may fit inflation expectations better. However, as previously explained, the model incorporating each industry has a larger in-sample RMSE. Even when forecast accuracy is calculated by adding one other industry to the consumer-related industries, we find no set in which the out-of-sample RMSE is smaller than that for consumer-related industries alone. These results indicate that the relationship between corporate and consumer prices may change over time or may not be linear.

The Tankan includes questions concerning actual and future changes in the company's input prices, and the results are published as the "Change in Input Prices DI." We also attempt to conduct the analysis using the input price DI instead of the output price DI or the accompanying output price DI. Nonetheless, the RMSE is not reliably smaller than that of Set 6. This result suggests that information about input prices that can affect inflation expectations is factored into the output price, DI.

4-3. Connecting estimated and observed inflation expectations

The long-run time series of inflation expectations are from the December 1990 survey, from which the Tankan "Services" sector output price DI is obtained, to the most recent survey. Figure 3 shows the long-run time series of the estimated inflation expectations. The shaded ranges denote 95% confidence intervals calculated using the Monte Carlo method. A comparison with the (observed) CPI inflation expectation data in Figure 3 shows that the estimates fit the observed values reasonably well. However, a divergence with observations outside the 95% confidence interval is observed for the March–December 2014 survey. Our long-run time series of inflation expectations are the estimated values up to the December 2013 survey and the observed values as of March 2014. Because of the divergence between the December 2013 and March 2014 survey observations, connecting them seems inappropriate.

We consider connecting the estimated values up to the December 2013 survey with the observed values from the March 2014 survey, minimizing distortion to the time series character of the estimates. Specifically, we estimate an autoregressive moving-average (ARMA) model for the estimated values up to the December 2013 survey. After searching for the formulation that minimizes the AIC for the order of the AR term (0–3 lags), the order of the MA term (0–3 lags), and with and without a mean parameter, we select the ARMA(1, 1) model with no mean parameter.

Despite being an ad hoc approach, we discount the difference between the estimated and observed values in the March 2014 survey backward at a set rate from December 2013 and add it to the estimate, creating a connection. We use r as the discount rate and g as the observed value that is less than the estimated value in the March 2014 survey. Taking the estimated inflation expectation values as $\hat{y}_t$ and $\hat{\hat{y}}_t$ as the values corrected for this connection, we correct the estimated values before December 2013 using the following equation:

$$\hat{\hat{y}}_t = \hat{y}_t + gr^{T-t}, \quad t = 1, \dots, T-1,$$

where T denotes the March 2014 survey. The size of correction decays moving backward through the sample period: gr for the December 2013 estimate value, gr^2 for September 2014, gr^3 for June 2014, and so on.

Regarding the discount rate r, inserting the values from the corrected time series into the ARMA(1, 1) model estimated above yields the r with the smallest in-sample RMSE for the four quarters before and after the connection period, from September 2013 to June 2014. We obtain $r = 0.852$. We correct the estimated values based on this r value to connect them with the observed values from the March 2014 survey. This correction is preferable, because the connection using this discount rate increases the accuracy of the inflation rate forecast.

4-4. Long-run inflation expectations series

Figure 4 shows the estimated firms' inflation expectation; inflation expectations of 1–2% in the early 1990s hovered at approximately 0% since the late 1990s. They rose to approximately 1% around 2006–2008 amid rising oil prices but receded to 0% amid the reactionary fall in oil prices and the global financial crisis. Inflation expectations increased around 2013 and have since hovered at approximately 1%. Notably, in 2013, the Bank of Japan introduced the 2% price stability target alongside Quantitative and Qualitative Monetary Easing; these policies may have raised inflation expectations. Inflation expectations subsequently jumped 2–3% from 2022 due to surging commodity prices and other factors.

A comparison of the actual CPI inflation rate (total, excluding fresh food, energy, and special factors; year-on-year; the same holds below)[5] and firms' inflation expectations, as shown in Figure 4, suggests that movements in inflation expectations yield valuable information for predicting the actual inflation rate. The large decline in inflation in the early 1990s and the increase in inflation in the late 2000s and 2013–2015 show that inflation expectations anticipate the actual movements. Table 4 shows the time lag correlation between the CPI inflation rate and the firms' inflation expectations, which is about 0.8 one year ahead (four quarters), suggesting a considerably high correlation.

While the actual values are larger and more negative around 2000 and 2010, inflation expectations are higher than these values, resulting in divergence. In 2010, particularly after the global financial crisis, inflation expectations fell to approximately 0.5%, while the actual figure declined to nearly 1.5%. This phenomenon may be due to the downward rigidity in inflation expectations, as noted by Gorodnichenko and Sergeyev (2021), which may also manifest in the inflation expectations estimated in this study.

Figure 4 compares the one-year-ahead inflation expectations in Consensus, as an economists' forecast, with firms' inflation expectations. While similar on average, closer scrutiny reveals crucial differences in their relationships with the actual inflation rate. Economists' forecasts are characteristically higher in the first half of 1990, whereas corporate inflation expectations are higher in 2022. Turning to the actual figures, and as noted above, firms' inflation expectations are more preemptive to the significant decline in inflation rates in the early 1990s and the sharp increase in inflation in 2022. These trends suggest that firms' inflation expectations yield more information on future inflation rates than economists' forecasts.

We use a Granger causality test to examine the relationship between firms' inflation expectations and inflation. In the Granger sense, we consider the no-causality null hypothesis where the lag length in the forecast is four quarters. Table 5 presents the causality test results, in which the null hypothesis of no causality from firms' inflation expectations to CPI is rejected at the 1% level. However, we do not reject the null hypothesis of no reverse causality. This finding suggests, as Fuhrer (2012) discussed, that inflation expectations contain information that can predict future CPI inflation rates. Applying the same causality test to economists' inflation expectations yields the same results.

Next, we analyze the role of inflation expectations in forecasting CPI inflation rates. Coibion et al. (2018) examine whether, in addition to standard macroeconomic variables

[5] The CPI inflation rate series used here is the figure estimated by Bank of Japan staff, which excludes mobile phone charges and the effects of the consumption tax hikes, policies concerning the provision of free education, and travel subsidy programs.

such as the output gap, inflation expectations hold information that complements the explanatory power provided by those variables. We examine whether firms' inflation expectations contain information that complements the explanatory power of these economic variables. By estimating a regression equation in which the explained variable is the CPI inflation rate and the explanatory variables are the CPI inflation rate one quarter before, the output gap, and the nominal effective exchange rate, we also estimate a regression equation in which firms' inflation expectations are added. The estimation period is from December 1990 to December 2021. The 2022 sample is close to the end of the output gap estimate, and since it may be revised to some extent in the future, the end of the estimation period is set to 2021.

Table 6 presents the regression analysis results. First, the coefficients of all the explanatory variables are statistically significant in the regression equation without firms' inflation expectations. Next, the coefficients of the previous explanatory variables remain statistically significant in the regression equation with added firms' inflation expectations. The key finding is that the coefficients of firms' inflation expectations are also significant. This result shows that firms' inflation expectations contain information that is not included in conventional macroeconomic variables.

Finally, we verify whether firms' inflation expectations improve the accuracy of a simple inflation forecast model. Using the data for the period up to the December 2014 survey, we estimate a regression equation taking the above inflation rate as the explained variable and using the explanatory variables from the December 2014 survey to predict the inflation rate for the March 2015 survey. Then, we add the March 2015 survey to the data and use it to project the inflation rate for the June 2015 survey. We iteratively calculate the values to obtain predicted values up to December 2021. By changing the lag of the explanatory variable from one quarter to two quarters, we calculate the expected values two quarters forward. In other words, we use data up to the December 2014 survey to forecast the inflation rate for the June 2015 survey. Moreover, by setting this lag to three or four quarters, we obtain forecast values for three or four quarters ahead. We repeat these forecasts, adding one-quarter of the data at a time until forecast values are available for the December 2019 survey, up to the COVID-19 outbreak, which produces 20 quarters of forecasts. We validate this forecast analysis by including and excluding the firms' inflation expectations.[6]

Table 7 presents the RMSE of the difference between the forecast and actual CPI values. For quarters 1–4 ahead, the RMSE is smaller, and the forecast accuracy is higher when using

[6] Note that the inflation expectations used here are estimated using samples for the entire period, so the analysis is not based on strictly real-time forecast.

firms' inflation expectations. We test whether the difference in the RMSE is statistically different from zero using the Model Confidence Set (MCS) method proposed by Hansen et al. (2011). We find that using firms' inflation expectations offers substantially greater accuracy at the 5% level for forecasts four quarters ahead. This result indicates that the inflation expectations presented in this analysis contain information that improves the accuracy of one-year-ahead forecasts.[7]

We also calculate forecast accuracy using economists' forecasts instead of firms' inflation expectations. We find that firms' inflation expectations improve forecast accuracy more than economists' forecasts do for all 1–4 quarters ahead, as shown in Table 7. Applying the MCS test to the difference in their RMSE shows that at the 5% level, the difference between the first and second quarters ahead is not statistically significant. Conversely, the difference between the third and fourth quarters is statistically significant. Similar results are obtained for the forecasted analysis even when the measurement period is extended beyond 2020. This result indicates that the firms' inflation expectations estimated in this study are significantly more informative in predicting inflation three or four quarters ahead of economists. As discussed above, this suggests that, as price-setters of consumer goods and services, firms' inflation expectations are essential in determining the inflation rate.

5. Concluding remarks

This study uses the output price DI from the Tankan survey to create a long-run time series of Japanese firms' inflation expectations from 1990. After testing various variables and estimation equations, we find that estimates with higher forecasting accuracy can be obtained using the output price DI in combination with the inflation outlook for the company's output prices. Estimated inflation expectations contain information not available in other standard macroeconomic variables, which can improve the forecasting accuracy of a simple inflation-forecasting model.

Discussing whether a selected series of inflation expectations is "correct" is challenging because the true figures are unknown. It is essential to compare this series with other inflation expectation measures. Given the extremely limited availability of such time-series data, the series presented in this study can increase the number of inflation expectation series available for reference, expand the breadth of analysis, and confirm its robustness.

One caveat of the proposed framework is that all relational equations are assumed to

[7] The same forecast accuracy calculations for the series of inflation expectations calculated from the candidate variable sets and estimation equations in Section 4-1 reveal the RMSE to be smallest when using the selected estimated inflation expectation.

be linear. Although a non-linear relationship exists between the two variables that construct the relational equation, only 32 quarterly counts exist between March 2014 and December 2021. Therefore, the sample size is insufficient to determine a non-linear relationship. The framework posits a linear relationship between the DI created by aggregating qualitative responses and inflation expectations. The (forecast) output price DI is the percentage of firms that answer that their output prices "rise" over the next three months minus the percentage of firms that respond that their output prices "fall." Thus, it can only take values ranging from -100 to 100. While Pinto et al. (2020) show that a DI constructed in this manner may precisely approximate the average responses to inflation expectations, the theoretical relationship between the distribution of respondents to DI items behind the DI and the average responses to inflation expectations is beyond the scope of this study.

This study estimates short- and one-year-ahead inflation expectations. However, medium- and long-term inflation expectations are necessary for various empirical analyses. Appendix B addresses them using an additional time-series model and the "Annual Survey of Corporate Behavior" results to forecast Japanese firms' medium- and long-term inflation expectations. Interpreting the results requires some ranges when estimating inflation expectations several years into the future based on the actual and forecasted output price DI. Another caveat is that a series created using only short-term information does not adequately capture inflation expectations specific to medium- to long-term durations due to, for example, inflation targets. Hence, continuing uninterrupted survey research, such as the Tankan survey, on medium- to long-term firms' inflation expectations is vital.[8]

[8] The series of inflation expectations proposed in this paper is published and updated at the author's website, https://sites.google.com/site/jnakajimaweb/einf.

Appendix A. Tankan price outlook survey methodology

The following are the questions and options for the "inflation outlook" in the Tankan, as of the December 2022 survey.

(1) Outlook for output prices

Relative to the current level, what is your enterprise's expectations for the rate of change in the selling price of your main domestic products or services for one year ahead, three years ahead, and five years ahead, respectively? Please select the range nearest to your own expectation from the options below.

Rate of changes relative to the current level

1. around +20% or higher (+17.5% or higher)
2. around +15% (+12.5% to +17.4%)
3. around +10% (+7.5% to +12.4%)
4. around +5% (+2.5% to +2.4%)
5. around 0% (-2.5% to +2.4%)
6. around -5% (-7.5% to -2.6%)
7. around -10% (-12.5% to -7.6%)
8. around -15% (-17.5% to -12.6%)
9. around -20% or lower (-17.6% or lower)
10. Don't know

(2) Outlook for general prices

What is your enterprise's expectations of year-on-year rate of change in general prices (as measured by the Consumer Price Index) for one year ahead, three years ahead, and five years ahead, respectively? Please select the range nearest to your own expectation from the options below.

In annual percent rate changes

11. around +6% or higher (+5.5% or higher)
12. around +5% increase year-on-year (+4.5% to +5.4%)
13. around +4% increase year-on-year (+3.5% to +4.4%)
14. around +3% increase year-on-year (+2.5% to +3.4%)
15. around +2% increase year-on-year (+2.5% to +3.4%)

16. around +1% increase year-on-year (+1.5% to +2.4%)
17. around 0% year-on-year (-0.5% to +0.4%)
18. around -1% year-on-year (-1.5% to -0.6%)
19. around -2% year-on-year (-2.5% to -1.6%)
20. around -3% or lower (-2.6% or lower)

If you have no clear views on general prices, please select one of the three following reasons.

21. Uncertainty over the future outlook is high
22. Not really conscious of inflation fluctuations because they should not influence the strategy of the enterprise
23. Other

Appendix B. Estimation of firms' medium- and long-term inflation expectations

As discussed in this study, estimating inflation expectations using the output price DI, a forecast up to three months ahead, is limited to one year ahead. Using the same framework to estimate medium- to long-term inflation expectations, such as those for three or five years, is challenging. However, medium- to long-term inflation expectations are essential when empirically analyzing inflation dynamics and policy effects. Because long-run time-series data candidates are limited to Japan, estimating firms' medium- to long-term inflation expectations using the Tankan DI significantly contributes to a wider body of literature.

Therefore, this appendix exploits the DI and inflation expectations from the Tankan to estimate a long-run time series of firms' medium- and long-term inflation expectations. Specifically, we use the time series model of inflation dynamics proposed by Kozicki and Tinsley (2012) to estimate medium- and long-term inflation expectations before 2013 using the output price DI (actual), the estimated one-year ahead inflation expectations, and the Tankan three- and five-year ahead inflation expectations. Because we observe the output price DI before 2013, supplementing it with information on medium- and long-term inflation expectations is necessary. For this purpose, we use three-year-ahead inflation expectations calculated from the results of the Cabinet Office's "Annual Survey of Corporate Behavior."

Appendix 2-1. Annual Survey of Corporate Behavior

The Annual Survey of Corporate Behavior (ASCB), conducted annually by the Cabinet Office, asks Japanese firms about their expectations on various macroeconomic variables. Figures on nominal and real GDP growth forecasts are available from the 2003 survey onward, making it possible to calculate the inflation expectations. The figures include "next year," "next three years," and "next five years" forecasts. Kaihatsu and Shiraki (2016) analyze the forward rate for 1–5 years using the next year and the next five years as medium- to long-term inflation expectations. This study uses this forward rate as the inflation expectations for three years ahead, midway between 1–5 years.

Because the 2003 survey of the ASCB was conducted in January 2004, it is considered almost the same time as the December 2003 survey of the Tankan for estimation purposes. As this was an annual survey, we use linear interpolation to create a quarterly series. Moreover, as seen from the indirect method of calculating inflation expectations discussed earlier, this series of inflation expectations corresponds to the GDP deflator forecast, which is expected to diverge from CPI inflation expectations. Therefore, we adjust the level so that the difference between the average three-year-ahead inflation expectations in the Tankan from the first quarter of 2014 to the fourth quarter of 2021 and the average of the relevant inflation expectations in the ASCB becomes zero. The adjustment range is 0.73 percentage points, consistent with the difference between the GDP deflator and the (aggregate) CPI inflation rate for 1995–2019, averaging 0.66 percentage points.

For the period before the fourth quarter of 2003, we extrapolate by regressing the series from the same quarter to the fourth quarter of 2021 on the variables considered to be determinants of inflation expectations three years ahead and calculating the theoretical value before the fourth quarter of 2003. Specifically, actual inflation in the previous quarter (the year-on-year CPI inflation rate), the trend in actual inflation (the average of the year-on-year CPI inflation rate over the past two years), and the nominal effective exchange rate (year-on-year) are estimated as regression variables. All the variables are statistically significant at the 5% level. Appendix Figure 1 presents the three-year ahead inflation expectations based on the ASCB. Following a gradual decline from 2% around 1992 to approximately 0.5% in the early 2000s, it remained steady until 2012. It then turned upwards.

Appendix 2-2. Time series model

For the time series model used in the estimation, we first define π_t as the inflation rate in period t. Following Kozicki and Tinsley (2012), we assume that the inflation rate follows the equation:

$$\pi_t = \mu_t + \phi(\pi_{t-1} - \mu_t) + \varepsilon_t, \;\; \varepsilon_t \sim N(0, \sigma^2). \qquad \text{(A1)}$$

Suppose that μ_t is constant, π_t follows a first-order autoregressive (AR) model. We assume that the time series of π_t is stationary, and $|\phi| < 1$. Calculating the conditional future expectation of π_{t+h} $(h \geq 1)$ based on the information up to period yields

$$\mathrm{E}_t[\pi_{t+1}] = (1-\phi)\mu_t + \phi\pi_t,$$

$$\mathrm{E}_t[\pi_{t+2}] = (1-\phi^2)\mu_t + \phi^2\pi_t,$$

$$\cdots$$

$$\mathrm{E}_t[\pi_{t+h}] = (1-\phi^h)\mu_t + \phi^h\pi_t. \qquad \text{(A2)}$$

Thus, we obtain:c

$$\lim_{h\to\infty} \mathrm{E}_t[\pi_{t+h}] = \mu_t.$$

where μ_t represents the expected convergence point that the inflation rate will reach, conditional on the information up to period t. Considering the discussion of inflation expectations, μ_t is viewed as the point of convergence of the inflation expectations term structure in period t and sometimes referred to as the trend inflation rate (see, e.g., Kaihatsu and Nakajima, 2018). Kozicki and Tinsley (2012) propose a framework for estimating the parameters of Equation (A1) by assuming that μ_t follows a random walk and fitting Equation (A1) to a series of past inflation values and Equation (A2) to periods ahead of inflation expectations.

Instead of actual inflation, this study creates a series of perceived inflation rates that reflect firms' perceptions of the inflation rate over the past year from the actual output price DI in Tankan and fits Equation (A1) to this series. The reason for not using actual inflation is to avoid using it twice in the same model because it is already used in the extrapolation of the ASCB described above. It also considers the possibility that firms emphasize their perceptions of inflation rates rather than actual inflation when forecasting inflation.

We denote the perceived inflation rate in period t as $\pi_{t|t}$ and the inflation for h periods ahead as $\pi_{t+h|t}$. As Tankan and the estimated inflation expectations are on a year-on-year basis, all variables in the model are assumed to be on a year-on-year basis, including the perceived inflation rate. We create estimates using the following equation as a model incorporating medium- and long-term inflation expectations:

(t up to the fourth quarter of 2013)

$$\begin{bmatrix} \pi_{t+1|t+1} \\ \pi_{t+4|t} \\ \tilde{\pi}_{t+12|t} \end{bmatrix} = \begin{bmatrix} 1-\phi \\ 1-\phi^4 \\ 1-\phi^{12} \end{bmatrix} \mu_t + \begin{bmatrix} \phi \\ \phi^4 \\ \phi^{12} \end{bmatrix} \pi_{t|t} + \begin{bmatrix} \epsilon_{1t} \\ \epsilon_{2t} \\ e_t \end{bmatrix}, \tag{A3}$$

(t from the first quarter of 2014)

$$\begin{bmatrix} \pi_{t+1|t+1} \\ \pi_{t+4|t} \\ \pi_{t+12|t} \\ \pi_{t+20|t} \end{bmatrix} = \begin{bmatrix} 1-\phi \\ 1-\phi^4 \\ 1-\phi^{12} \\ 1-\phi^{20} \end{bmatrix} \mu_t + \begin{bmatrix} \phi \\ \phi^4 \\ \phi^{12} \\ \phi^{20} \end{bmatrix} \pi_{t|t} + \begin{bmatrix} \epsilon_{1t} \\ \epsilon_{2t} \\ \epsilon_{3t} \\ \epsilon_{4t} \end{bmatrix}, \tag{A4}$$

(All periods)

$$\mu_{t+1} = \mu_t + v_t, \tag{A5}$$

where $\epsilon_{it} \sim N(0,\sigma_a^2)$, $e_t \sim N(0,\sigma_b^2)$, $v_t \sim N(0,w^2)$, for $i = 1,\ldots,4$; $\pi_{t+4|t}$ is the estimated inflation expectations one year ahead, $\pi_{t+12|t}$ and $\pi_{t+20|t}$ are the three- and five-year inflation expectations from the Tankan, and $\tilde{\pi}_{t+12|t}$ is the three-year inflation expectations from the ASCB. Since there are no Tankan inflation expectations series before the fourth quarter of 2013, the equation comprises three observation equations: two for the perceived inflation rate and the estimated inflation expectations one year ahead, plus the three-year ahead inflation expectations from the ASCB. The Tankan inflation expectations became available in the first quarter of 2014, resulting in four observation equations. The variance of the error term ϵ_{it} in the Tankan inflation expectations is set to be common to minimize the number of parameters, given the limited number of samples in the data series.

Kozicki and Tinsley (2012) apply their model to data from the U.S., fitting an AR (13) model, which has long lags, to inflation rate dynamics because the data series are monthly and available over considerably long periods. However, because the Tankan data are quarterly and the inflation expectations series cover only a short period, a simple AR(1) model is assumed to conserve the parameters.

We calculate the perceived inflation rate using the fact that the actual consumer-related industry output price DI series weighted by the CPI displays a high correlation with the inflation rate (total ,excluding fresh food, energy, and special factors, year-on-year). The correlation coefficient between the consumer industry output price DI and the inflation rate is high at 0.753 from the third quarter of 1991 to the fourth quarter of 2022. Furthermore, as the output price DI series is an evaluation for the most recent three months, the correlation coefficient increases to 0.851, when calculated with a series in which a backward four-period moving average is taken for the DI consistent with the inflation rate on a year-on-year basis. Therefore, the linear relationship between the two can be calculated by regressing the inflation rate on the output price DI. Since including a linear time trend would be statistically significant at the 1% level, we included time trends in the regression, and the results are used to estimate the theoretical value of the inflation rate based on the output price DI, that is, the perceived inflation rate in this analysis.

Appendix Figure 2 shows the estimated perceived inflation rate, which is similar to past inflation overall but features some differences in each phase. For example, actual inflation fell sharply into the negative territory in 2000, but the perceived inflation rate remained at approximately 0%. Moreover, while actual inflation rose to approximately 0% in 2003, the perceived inflation rate was as low as -1%.

Models (A3)–(A5) are estimated using the maximum likelihood method with a Kalman filter and a grid search. The range and increments of the grid search are, respectively, ϕ in the range [0.85, 0.99] with 0.01 increments, σ_a^2 in the range [0.01, 0.10] with 0.01 increments, σ_b^2 in the range [0.1, 0.2] with 0.01 increments, and w in the range [0.1, 0.2] with 0.01 increments. The estimation period runs from the third quarter of 1991 to the fourth quarter of 2022, during which the perceived inflation rate is available. For simplicity, the initial distribution of μ_t is set from actual inflation immediately before the start of the estimation period and is set based on actual inflation in the second quarter of 1991 (3.0%) and the variance (0.15) for the two years immediately preceding (i.e., from the third quarter of 1989 to the second quarter of 1991), that is, $\mu_1 \sim N(3.0, 0.15)$. For $\pi_{t+1|t+1}$ in the fourth quarter of 2022, which is the end of the sample period, we compute it as the observed value of five-year ahead inflation expectations is inserted into $\pi_{t|t}$ in the first row of equation (A3), with its error term assumed to be zero.

Appendix 2-3. Estimation result

We obtain parameter estimates $\phi = 0.86$, $\sigma_a^2 = 0.07$, $\sigma_b^2 = 0.12$, and $w = 0.14$. Appendix Figure 3 shows the estimated value of μ_t, labeled "trend inflation," and the five-year ahead inflation expectations estimated based on the estimated parameters and the value of μ_t. Trend inflation is consistently around the same level as the 5-year ahead inflation expectations. This is because the term structure of the inflation expectations is shaped to reach the convergence point level comparatively quickly, as ϕ is not so close to one. The characteristics of the term structure of inflation expectations are shown in Appendix Figure 4, which shows an estimated 1–10 years ahead of inflation expectations. This finding is consistent with the empirical study by Maruyama and Suganuma (2019), who estimate inflation expectation curves from data on various inflation expectations in Japan.

Appendix Figure 5 shows the estimated five-year-ahead inflation expectations and their 95% confidence interval. The observed values (actual Tankan values) fall within this interval, except for a small portion of the 2021 period, indicating that the estimate is a good fit. From approximately 1.5% in 1992, five-year ahead inflation expectations continued intermittently, declining to approximately 1% in 1995 and 0.5% in 2000. Subsequently, it increased around 2012 to slightly above 1.5% in 2014. Appendix Figure 6 shows the estimated values for trend inflation, and its 95% confidence interval indicates almost the same movements as the five-year-ahead inflation expectations. In prior studies, firms' inflation expectations estimated in this analysis were somewhat lower in 1990 than the long-term inflation expectations estimated by Hogen and Okuma (2018) and Maruyama and Suganuma (2019). However, their movement remained unchanged throughout the sample period.

The five-year-ahead inflation expectations form a series that uses the estimated five-year-ahead inflation expectations up to the fourth quarter of 2013 and the observed Tankan data from the first quarter of 2014. Inflation expectations two and four years ahead are the estimated values obtained from the model used in this analysis for the entire period. However, from the first quarter of 2014 onwards, to maintain consistency with the observed values for one, three, and five years ahead, we slightly adjusted the differences between the observed and estimated values for these maturities. Specifically, after rounding up the estimated values for one year- and three-years-ahead of the first decimal place, we take the difference from the observed values, average them for one year ahead and three years ahead, and obtain the estimate for the two-year-ahead series (rounded to one decimal place). Similarly, the average difference was calculated from the three-year and five-year future series and added to the four-year estimate. The estimated term structure for six years or more is almost at the same level as that for five years ahead. Therefore, we set inflation expectations six years or more ahead as the value of the five-year-ahead series.

Appendix Figure 7(1) shows the estimated firms' and economists' five-year forward inflation expectations from the Consensus. During the 1990s and the 2000s, firms' inflation expectations were lower than economists' expectations, and the difference between the two averages was approximately 0.5%. In the late 1990s and the 2000s, economists' inflation expectations rose to approximately 1.5%; however, no such movement was observed for firms' inflation expectations. Appendix Figure 7(2) shows the estimated firms' trend inflation and economists' six- to 10-year inflation expectations. These show similar differences from the five-year inflation expectations.

We test the estimated firms' five-year-ahead inflation expectations and economists' inflation expectations by performing the same analysis as in the main analysis to identify differences in forecast accuracy in the inflation-forecasting models. Specifically, RMSEs were calculated one to eight quarters ahead of inflation expectations from the first quarter of 2015 to the fourth quarter of 2019. Note that the forecast is not fully based on real-time data, a caveat of this forecast analysis.

Appendix Table 1 presents the results, which show little difference in forecast accuracy for the first five quarters. Meanwhile, the forecast accuracy for the 6th–8th quarters is higher when firms' inflation expectations are used. As in the main study, statistical tests were conducted on these differences in predictive accuracy, but they were insignificant, even at the 10% level. Although this does not yield statistical significance, the estimated firms' inflation expectations contain information about their expectations as price-setters, suggesting that they may include at least as much information about the future path of the inflation rate as economists' inflation expectations and may be useful for macroeconomic analysis.

References

Adachi, K., and K. Hiraki (2021) "Recent developments in measuring inflation expectations: With a focus on market-based inflation expectations and the term structure of inflation expectations," *Bank of Japan Research Laboratory Series*, No. 21-E-1.

Coibion, O., Y. Gorodnichenko, and R. Kamdar (2018) "The formation of expectations, inflation, and the Phillips curve," *Journal of Economic Literature*, 56(4), pp. 1447-1491.

Coibion, O., Y. Gorodnichenko, and S. Kumar (2018) "How do firms form their expectations? New survey evidence. *American Economic Review*, 108(9), pp. 2671-2713.

Coibion, O., Y. Gorodnichenko, S. Kumar, and M. Pedemonte (2020) "Inflation expectations as a policy tool?" *Journal of International Economics*, 124, 103297.

Fuhrer, J. (2012) "The role of expectations in inflation dynamics," *International Journal of Central Banking*, 8(S1), pp. 138-165.

Gorodnichenko, Y., and D. Sergeyev (2021) "Zero lower bound on inflation expectations," NBER Working Paper Series, No. w29496.

Hajdini, I., E. S. Knotek, J. Leer, M. Pedemonte, R. W. Rich, and R. Schoenle (2022) "Indirect consumer inflation expectations: Theory and evidence," Federal Reserve Bank of Cleveland Working Paper Series, No. 22-35.

Hansen, P. R., A. Lunde, and J. M. Nason (2011) "The model confidence set," *Econometrica*, 79, pp. 453-497.

Hiraki, K., and W. Hirata (2020) "Market-based long-term inflation expectations in Japan: A refinement on breakeven inflation rates," Bank of Japan Working Paper Series, No. 20-J-5.

Hogen, Y., and R. Okuma (2018) "The anchoring of inflation expectations in Japan: A learning-approach perspective," Bank of Japan Working Paper Series, No. 18-E-8.

Hori, M., and M. Kawagoe (2013) "Inflation expectations of Japanese households: Micro evidence from a consumer confidence survey," *Hitotsubashi Journal of Economics*, 54, pp. 17-38.

Inatsugu, H., T. Kitamura, and T. Matsuda (2019) "The formation of firms' inflation expectations: A survey data analysis," Bank of Japan Working Paper Series, No. 19-E-15.

Kaihatsu, S., and N. Shiraki (2016) "Firms' inflation expectations and wage-setting behaviors," Bank of Japan Working Paper Series, No. 16-E-10.

Kaihatsu, S., and J. Nakajima (2018) "Has trend inflation shifted?: An empirical analysis with an equally-spaced regime-switching model," *Economic Analysis and Policy*, 59, pp. 69-83

Kamada, K., J. Nakajima, and S. Nishiguchi (2015) "Are household inflation expectations anchored in Japan?" Bank of Japan Working Paper Series, No. 15-E-8.

Kikuchi, J., and Y. Nakazono (2021) "The formation of inflation expectations: Microdata evidence from Japan," *Journal of Money, Credit and Banking*, in press.

Kitamura, T., and M. Tanaka (2019) "Firms' inflation expectations under rational inattention and sticky information: An analysis with a small-scale macroeconomic model," Bank of Japan Working Paper Series, No. 19-E-16.

Kozicki, S., and P. A. Tinsley (2012) "Effective use of survey information in estimating the evolution of expected inflation," *Journal of Money, Credit and Banking*, 44(1), pp. 145-169.

Maruyama, T., and K. Suganuma (2019) "Inflation expectations curve in Japan," Bank of Japan Working Paper Series, No. 19-E-6.

Nakajima, J., H. Yamagata, T. Okuda, S. Katsuki, and T. Shinohara (2021) "Extracting firms' short-term inflation expectations from the Economy Watchers Survey using text analysis," Bank of Japan Working Paper Series No. 21-E-12,

Nakazono, Y. (2016) "Inflation expectations and monetary policy under disagreements," Bank of Japan Working Paper Series, No. 16-E-1.

Nishiguchi, S., J. Nakajima, and K. Imakubo (2014) "Disagreement in households' inflation expectations and its evolution," *Bank of Japan Review*, No. 2014-E-1.

Nishino, K., H. Yamamoto, J. Kitahara, and T. Nagahata (2016) "Developments in inflation expectations over the three years since the introduction of Quantitative and Qualitative Monetary Easing (QQE)," *Bank of Japan Review*, No. 2016-E-13.

Pinto, S., P. D. Sarte, and R. Sharp (2020) "The information content and statistical properties of diffusion indexes," *International Journal of Central Banking*, 16(4), pp. 47-99.

Uno, Y., S. Naganuma, and N. Hara (2017) New facts about firms' inflation expectations: Simple tests for a sticky information model," Bank of Japan Working Paper Series, No. 18-E-14.

Figure 1. Tankan index of inflation expectations (all firm sizes and industries, one year ahead)

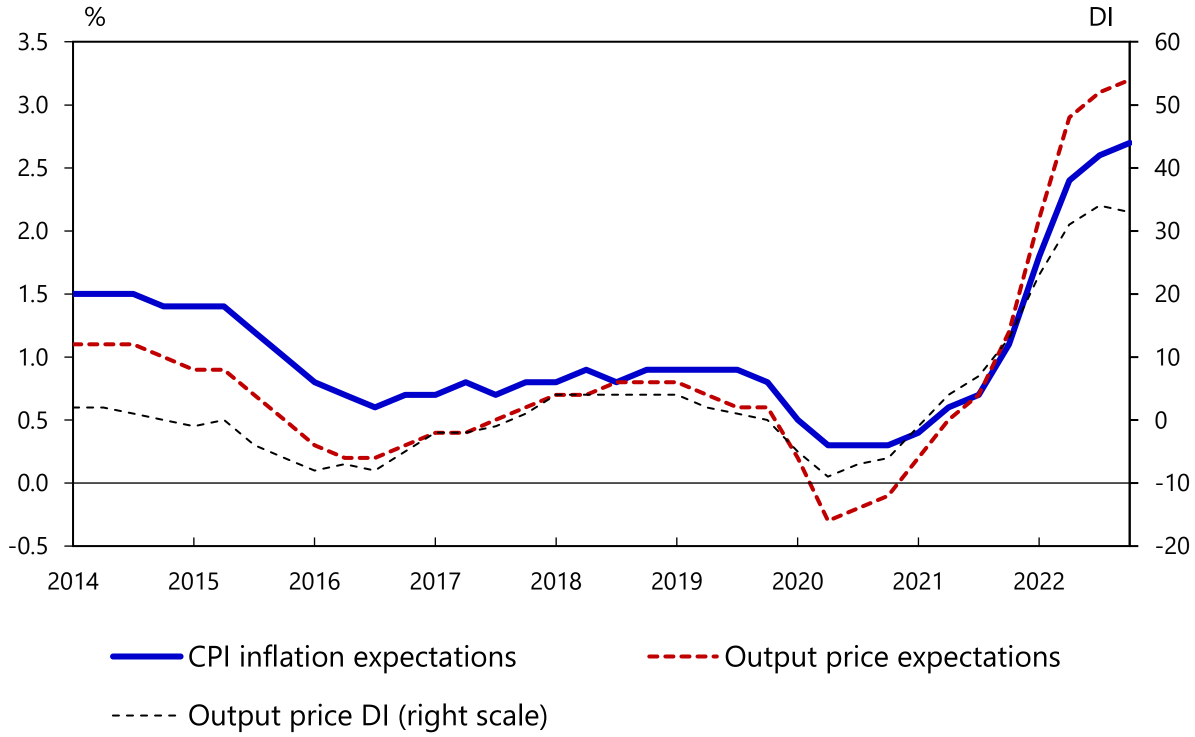
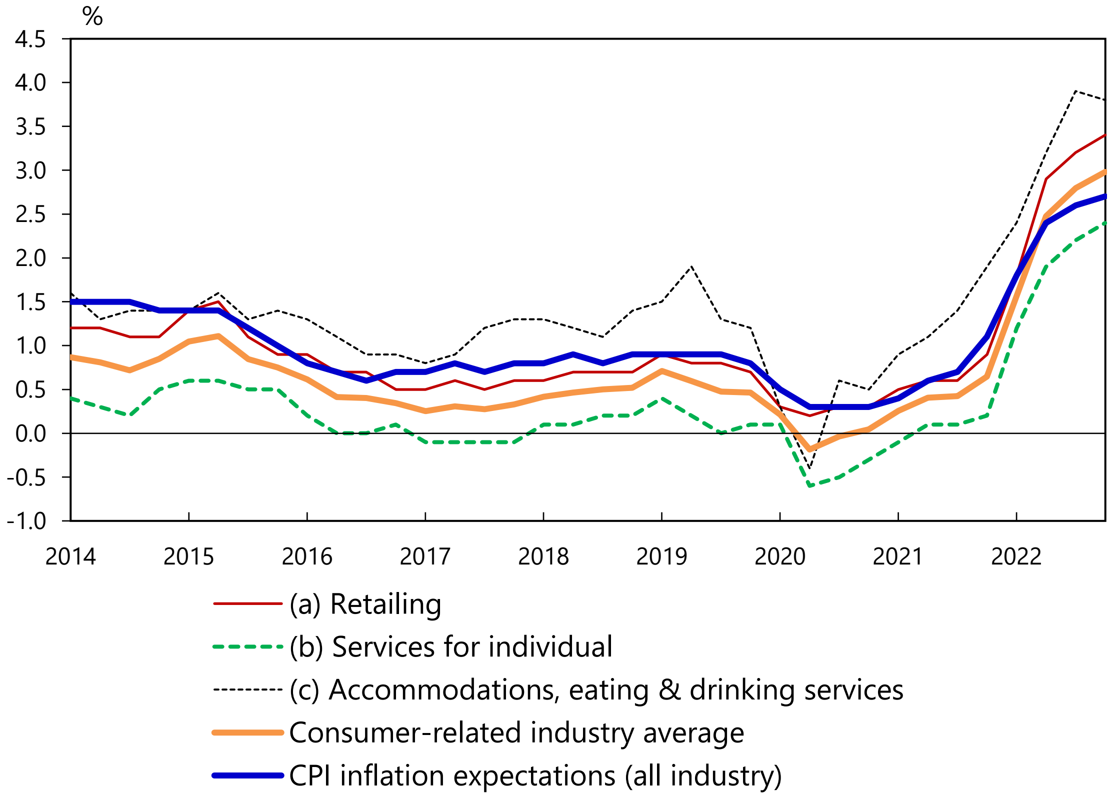
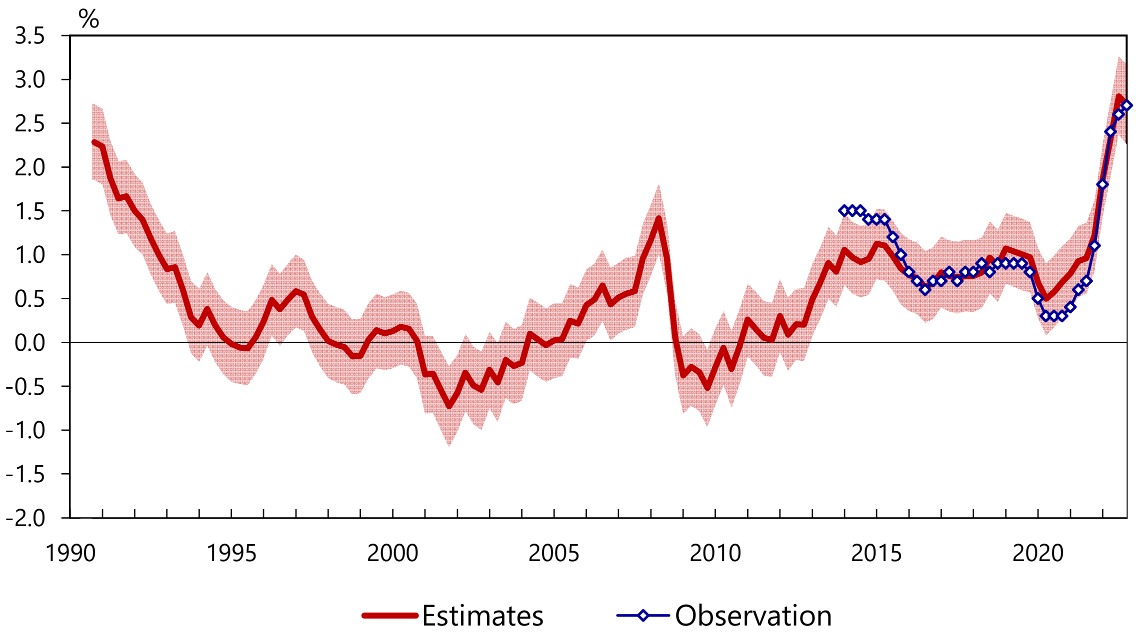


Figure 2. Tankan consumer-related industry output price expectations (all firm sizes, one year ahead)



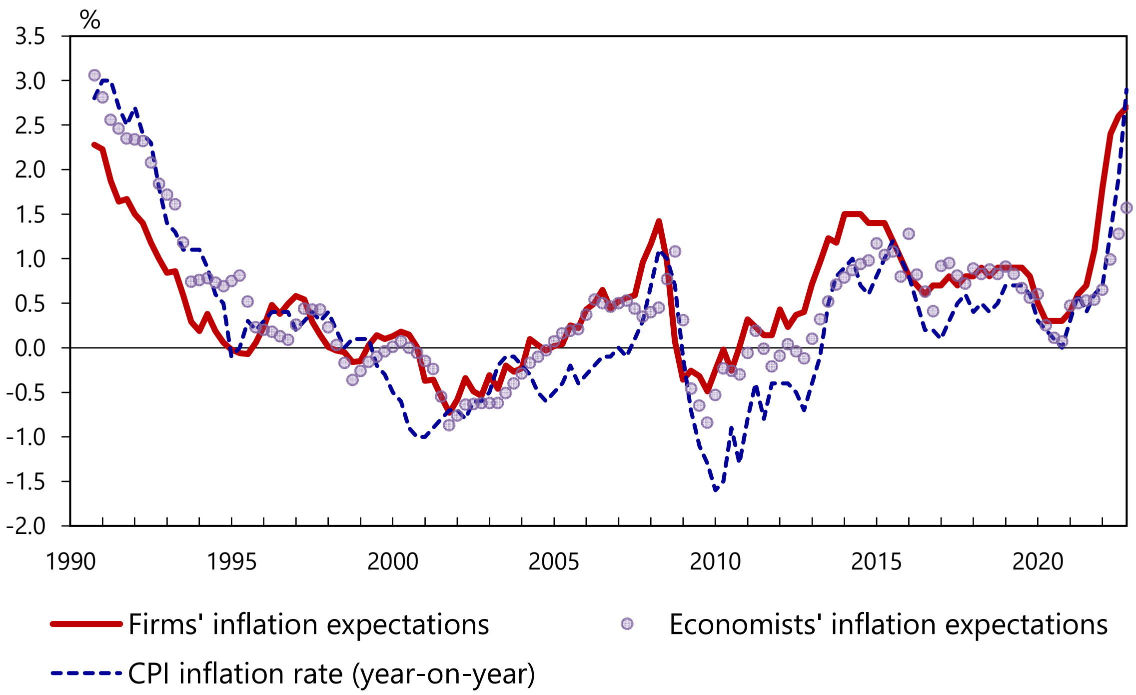
Note: Consumer-related industries are weighted averages of (a) through (c), according to their weight in the CPI (see the text for details).

Figure 3. Estimated and observed values of firms' inflation expectations (one year ahead)



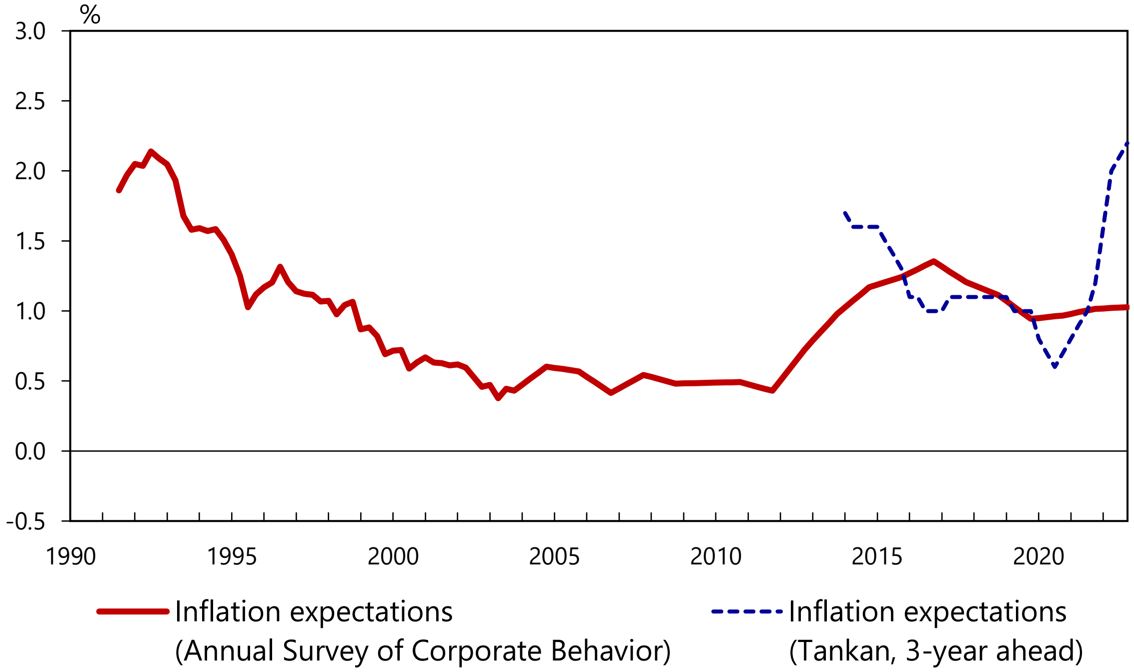
Note: The shadowed ranges show the 95% confidence interval for the estimates.

Figure 4. Estimated firms' inflation expectations and economists' inflation expectations

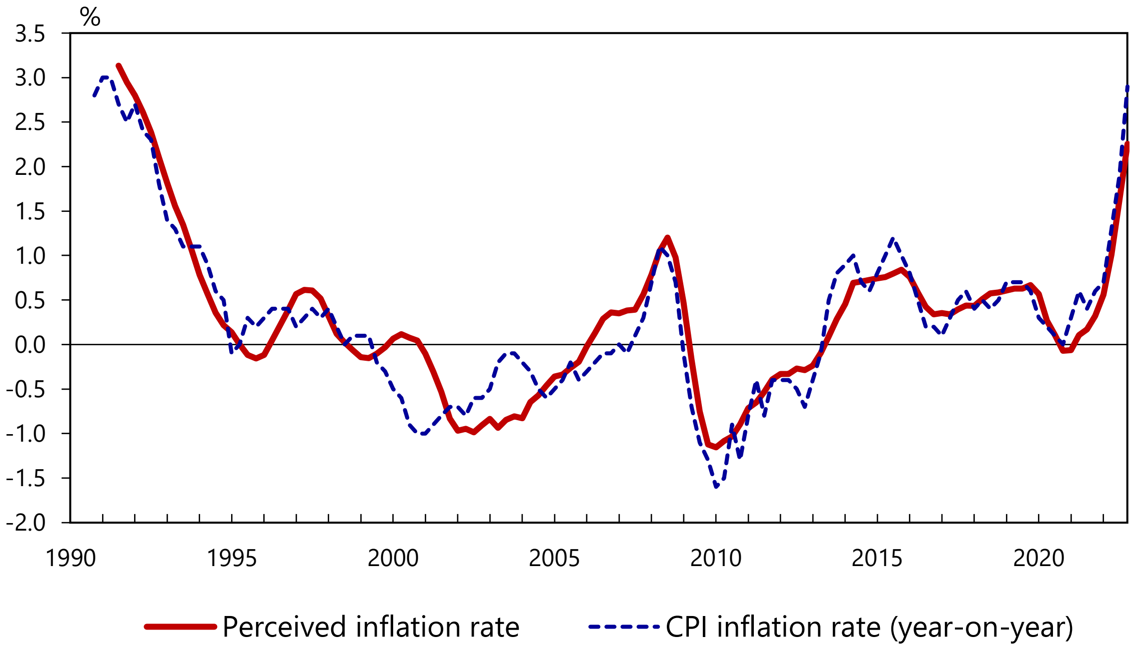


Note: The CPI inflation rate is the total, excluding fresh food, energy, and special factors (see the text for details). Economists' inflation expectations are based on the one-year-ahead Consensus forecasts.

Appendix Figure 1. Three-year ahead inflation expectations estimated from the Annual Survey of Corporate Behavior

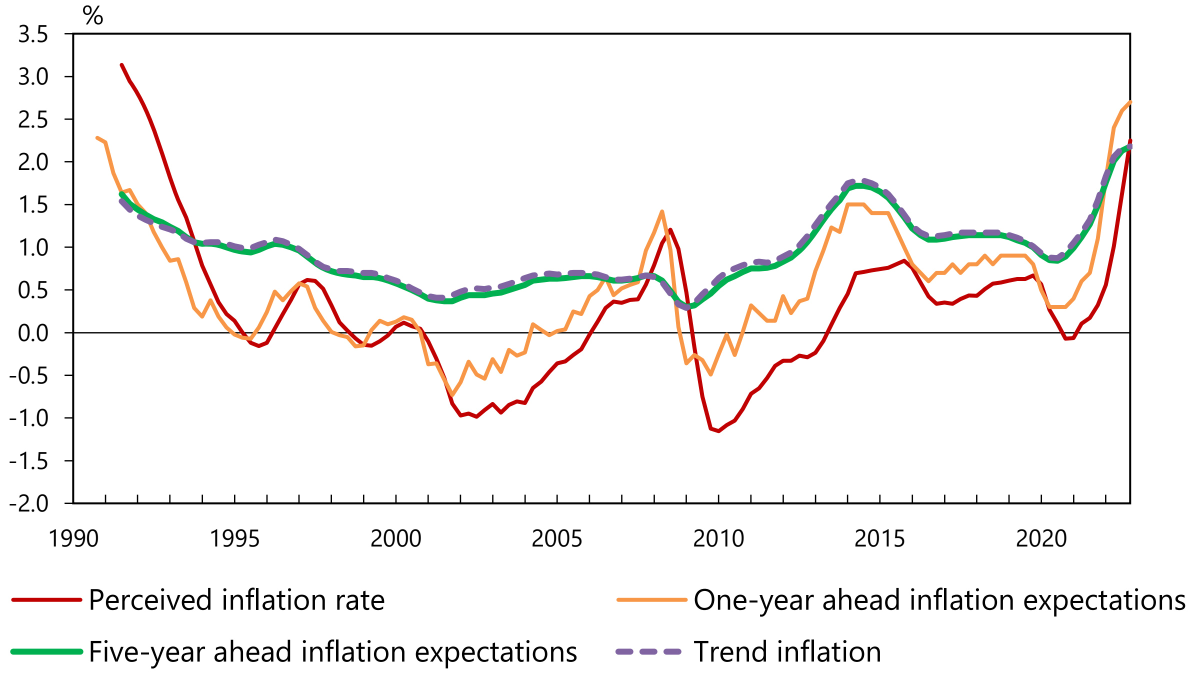


Appendix Figure 2. Estimated perceived inflation rate

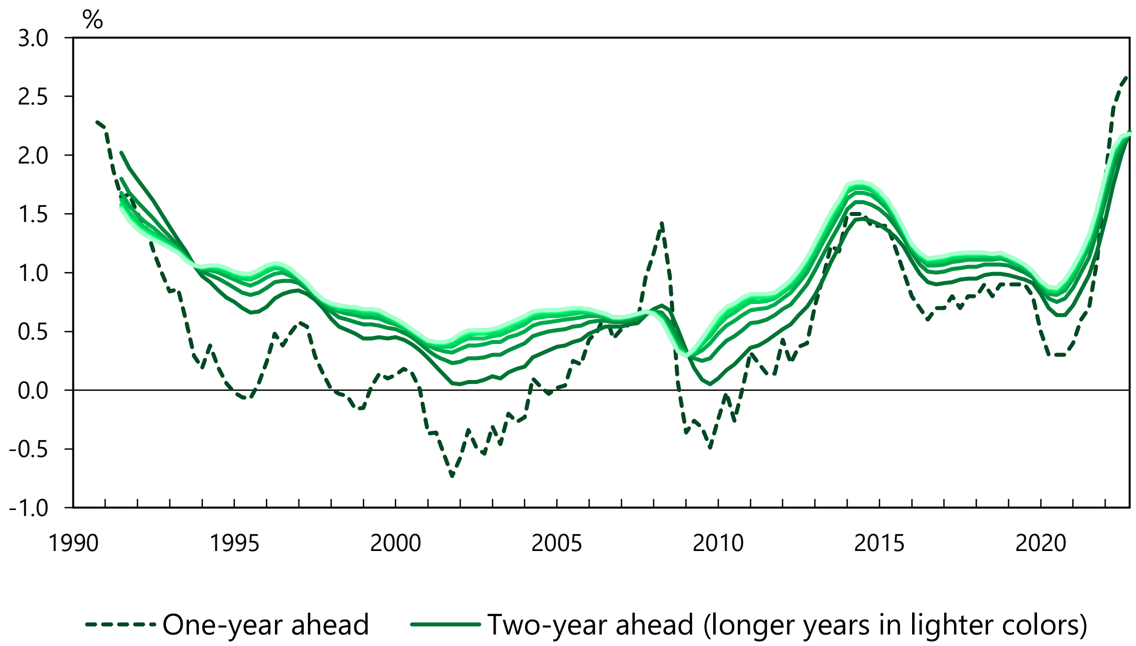


Note: The CPI inflation rate is the total, excluding fresh food, energy, and special factors (see the text for details).

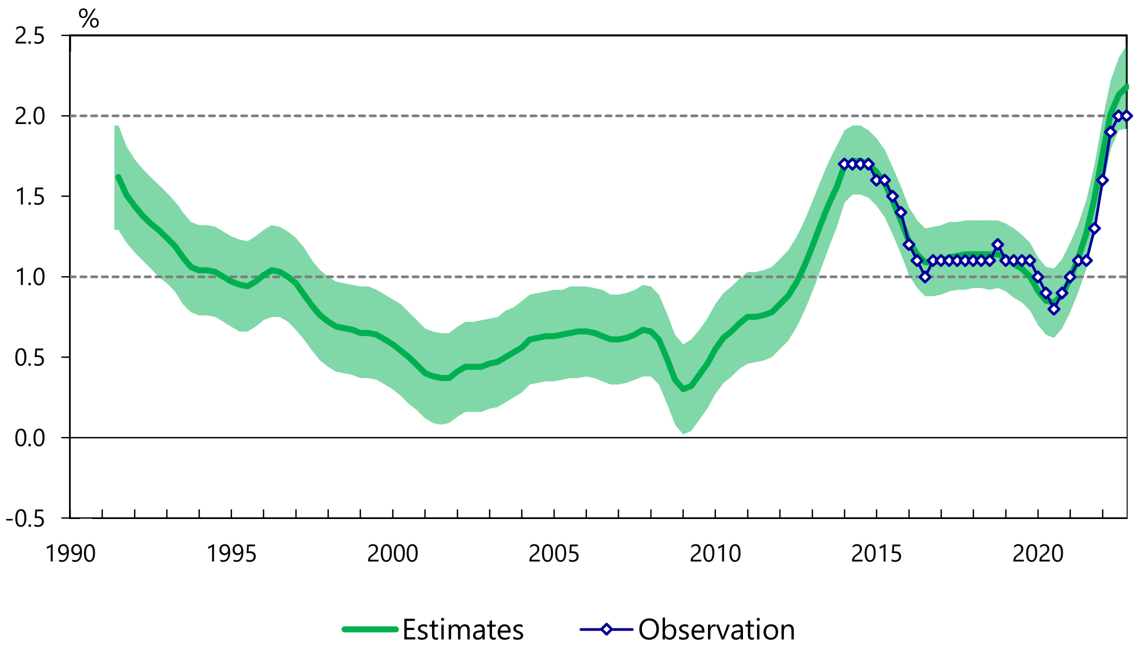
Appendix Figure 3. Estimates of firms' inflation expectations



Appendix Figure 4. Estimated term structure of firms' inflation expectations

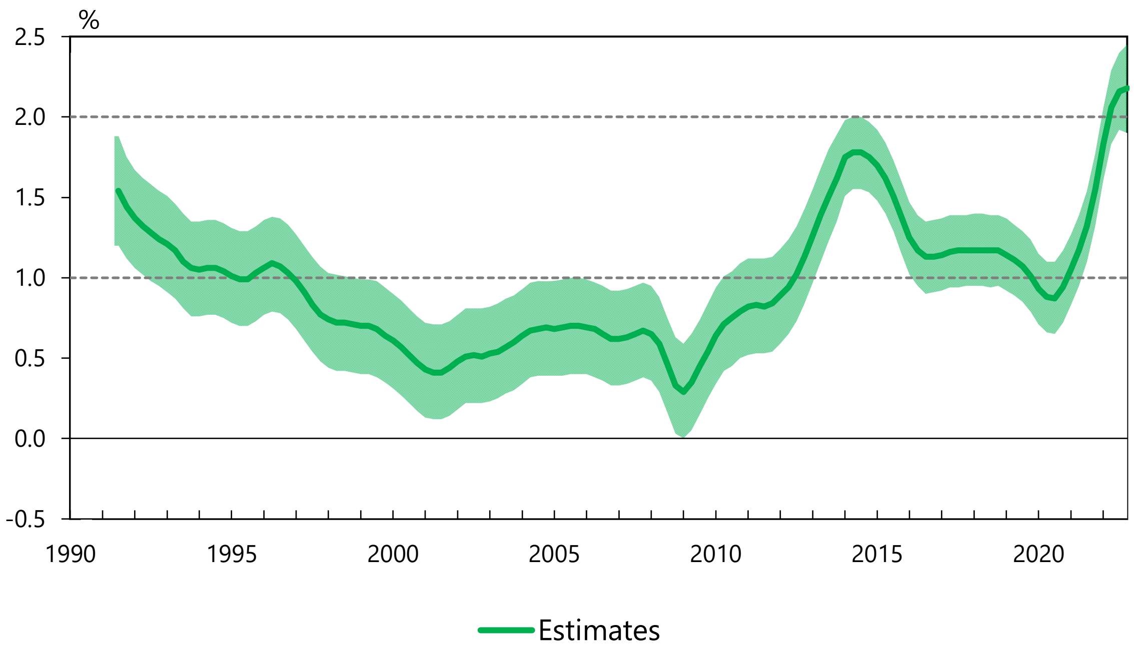


Appendix Figure 5. Estimated and observed firms' inflation expectations (5 years ahead)



Note: The shadowed ranges show the 95% confidence interval for the estimates.

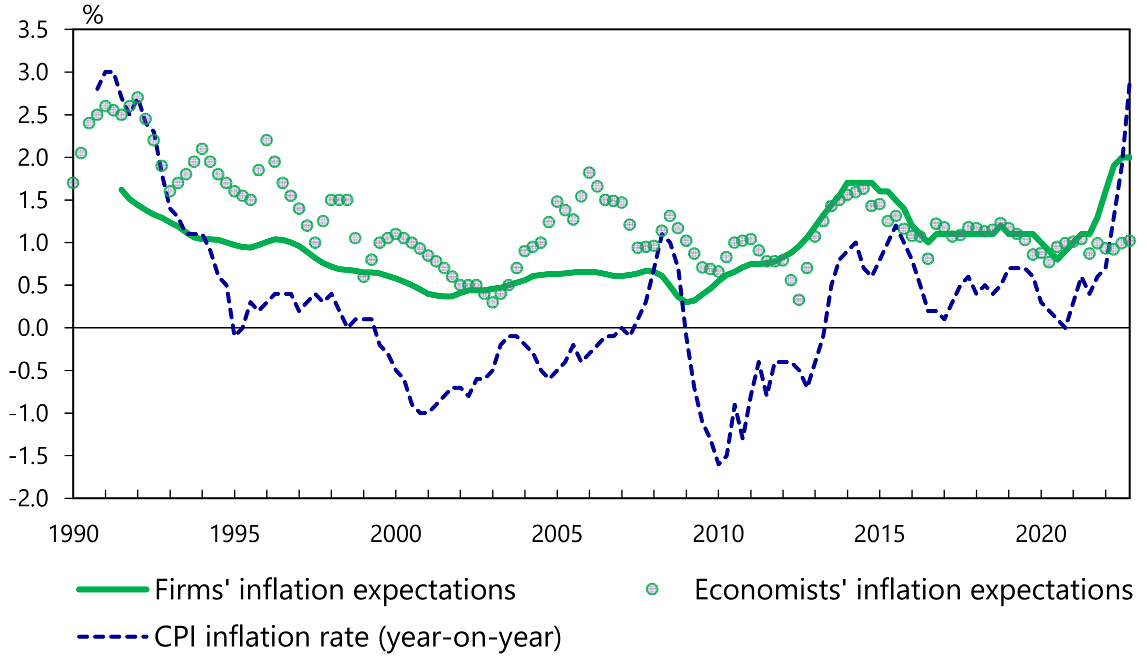
Appendix Figure 6. Estimates of firms' trend inflation



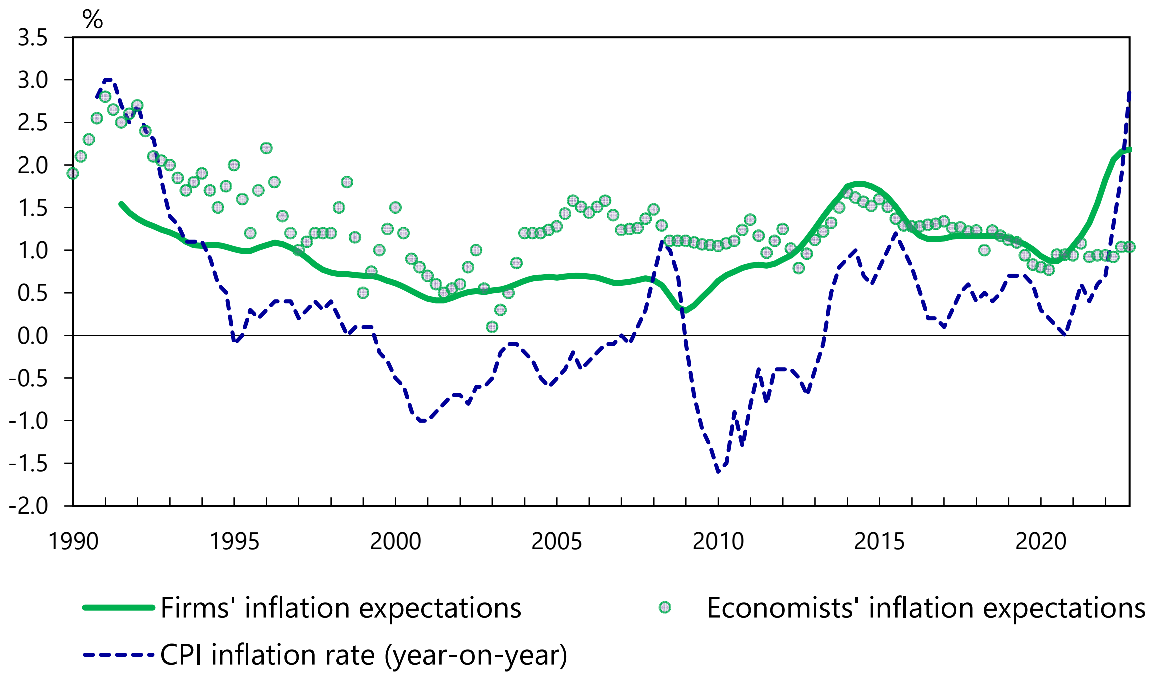
Note: The shadowed ranges show the 95% confidence interval for the estimates.

Appendix Figure 7. Firms' and economists' inflation expectations

(1) Five years ahead



(2) Trend inflation



Note: The CPI inflation rate is the total, excluding fresh food, energy, and special factors (see the text for details). Economists' inflation expectations are Consensus forecasts (trend inflation is 6–10 years ahead).

Table 1. Explanatory variables in the estimation model

Set	Explanatory variables	The number of variables
1	All industry average (all sizes)	1
2	Retailing (all sizes)	1
3	Consumer-related industry average (all sizes)	1
4	Retailing, Services for individual (all sizes)	2
5	Retailing, Accommodations, eating & drinking services (all sizes)	2
6	Retailing, Services for individual, Accommodations, eating & drinking services (all sizes)	3
7	Individual industries (all sizes)	23
8	Individual industries, individual sizes	69

Table 2. In-sample RMSE (from March 2014 to December 2022 surveys)

Set	1. One-step direct regression	2. Two-stage indirect regression	3. Two-stage weighted regression
1	0.3194	0.3225	—
2	0.2412	0.2415	—
3	0.2388	0.2391	—
4	0.2408	0.2417	0.2476
5	0.2230	0.2332	0.2307
6	0.2229	0.2327	0.2414
7	0.9674	0.3646	—
8	0.8300	0.3318	—

Table 3. Out-of-sample predictive accuracy (RMSE)

(1) From March 2018 to December 2022 surveys

Set	1. One-step direct regression	2. Two-stage indirect regression	3. Two-stage weighted regression
1	0.4006	0.4128	—
2	0.3146	0.3262	—
3	0.3268	0.3339	—
4	0.3563	0.3199	0.2991
5	0.3248	0.3141	0.2930
6	0.3523	0.3092	0.2830

(2) From March 2019 to December 2022 survey

Set	1. One-step direct regression	2. Two-stage indirect regression	3. Two-stage weighted regression
1	0.3783	0.3594	—
2	0.3494	0.3624	—
3	0.3493	0.3588	—
4	0.3751	0.3558	0.3233
5	0.3473	0.3474	0.3248
6	0.3715	0.3437	0.3040

(3) From March 2020 to December 2022 surveys

Set	1. One-step direct regression	2. Two-stage indirect regression	3. Two-stage weighted regression
1	0.4226	0.3869	—
2	0.3824	0.3980	—
3	0.3410	0.3592	—
4	0.3919	0.3919	0.3418
5	0.3950	0.3743	0.3477
6	0.4099	0.3712	0.3145

(4) From March 2021 to December 2022 surveys

Set	1. One-step direct regression	2. Two-stage indirect regression	3. Two-stage weighted regression
1	0.4195	0.4231	—
2	0.4196	0.4432	—
3	0.3892	0.4113	—
4	0.4418	0.4348	0.3430
5	0.3507	0.4172	0.3896
6	0.3711	0.4145	0.3165

Table 4. Time lag correlation coefficient between firms' inflation expectations and CPI inflation rate (year-on-year)

Inflation expectations lead (quarter)	Correlation
0	0.726
1	0.789
2	0.830
3	0.830
4	0.800
5	0.758
6	0.686
7	0.609
8	0.534

Note: The sample period is from the fourth quarter of 1990 to the fourth quarter of 2021. The CPI inflation rate is the total, excluding fresh food, energy, and special factors (see text for details).

Table 5. Results of the Granger causality test

Null hypothesis	F-value	p-value
a. Estimated firms' inflation expectations (one year ahead)		
Inflation expectations do not cause CPI inflation rate	9.086	0.000
CPI inflation rate does not cause inflation expectations	0.479	0.751
b. Economists' inflation expectations (one year ahead)		
Inflation expectations do not cause CPI inflation rate	6.157	0.000
CPI inflation rate does not cause inflation expectations	1.694	0.156

Note: The sample period is from the fourth quarter of 1990 to the fourth quarter of 2021. The lag length is four quarters. The CPI inflation rate is the total, excluding fresh food, energy, and special factors (see text for details). Economists' inflation expectations are based on the one-year-ahead Consensus forecasts.

Table 6. Determinants of the CPI inflation rate

Variables	Dependent variables: CPI inflation rate			
Lagged CPI inflation rate	0.852 ***	0.811 ***	0.890 ***	0.847 ***
	(0.031)	(0.021)	(0.034)	(0.028)
Output gap	0.071 ***	0.043 **	0.052 ***	0.036 **
	(0.024)	(0.024)	(0.021)	(0.022)
Exchange rate			-0.007 ***	-0.005 **
			(0.003)	(0.002)
Inflation expectations		0.184 ***		0.143 ***
		(0.052)		(0.060)
Constant	0.043 *	-0.037	0.041 **	-0.020
	(0.026)	(0.036)	(0.025)	(0.035)
Standard errors	0.207	0.195	0.197	0.191
Adjusted R-squared	0.946	0.952	0.951	0.954

Note: The sample period is from the fourth quarter of 1990 to the fourth quarter of 2021. The CPI inflation rate is the total, excluding fresh food, energy, and special factors (see text for details). The CPI inflation and exchange rates (nominal effective) are year-on-year values. We take a one-quarter lag for the output gap and the exchange rate. Figures in parentheses show Newey-West HAC standard errors. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 7. RMSE in forecasting CPI inflation (with one-year ahead inflation expectations)

Horizon (quarter)	a. Without inflation expectations	b. With firms' inflation expectations	c. With economists' inflation expectations
1	0.138	0.132	0.135
2	0.156	0.143	0.155
3	0.208	0.178	0.205 **
4	0.260	0.213 *	0.252 ***

Note: The forecast period is from the first quarter of 2015 to the fourth quarter of 2019. ***, **, * indicate that the difference between (a) and (b) for Column (b), and the one between (b) and (c) for Column (c) is statistically significant at the 1%, 5%, and 10% level, respectively.

Appendix Table 1. RMSE in forecasting CPI inflation (with five-year ahead inflation expectations)

Horizon (quarter)	With firms' inflation expectations	With economists' inflation expectations
1	0.138	0.136
2	0.162	0.152
3	0.226	0.212
4	0.284	0.300
5	0.329	0.380
6	0.373	0.478
7	0.413	0.572
8	0.432	0.639

Note: The forecast period is from the first quarter of 2015 to the fourth quarter of 2019.