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Abstract

This study uses the Bank of Japan's *Tankan* (Short-Term Economic Survey of Enterprises in Japan) results 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 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 using 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 essential for various 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). In addition to survey research, another method used to generate data for financial market participants' expectations is to extract inflation expectations from the prices of financial instruments traded in financial markets.[1] However, data for expectations of economists, households, and firms 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, and each is used in empirical analyses.

Inflation expectations can vary in changes and determining factors depending on the entity making the 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, firms' inflation expectations can be considered particularly important in empirical analyses in macroeconomics.

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 for inflation expectations. The inflation expectations data that can be traced back to the past the most is contained in the Cabinet Office's "Annual Survey of Corporate Behavior," only going back to 2003.[2] Moreover, the survey is only conducted annually. This lack of long-run time series data on firms' inflation expectations is a problem faced by researchers not only in Japan but also other countries, as pointed out by Coibion et al. (2020).

The output price diffusion index (DI) in the Tankan is often used as a proxy variable in

[1] Specifically, the inflation swap rate or the difference between the interest rate on nominal government bonds and inflation-indexed government bonds are often used. See Hiraki and Hirata (2020) for further details.

[2] The survey does not directly ask about inflation expectations but asks about 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.

the analysis of Japanese firms' inflation expectations. The output price DI includes queries of "actual" (current) and "future." 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 for the average series for all industries and sizes. In addition, series by industry and size are also maintained. Meanwhile, Nakajima et al. (2021) attempt to extract firms' inflation expectations since the 2000s using the text data of survey respondents' comments accompanying the Cabinet Office's "Economy Watchers Survey." The results indicate that the extracted series can be interpreted as inflation expectations for several months ahead. While these data are useful as a long-run time series of inflation expectations, they are inflation expectations for only several months ahead.

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 forecasts here are based on "outlook for general price inflation expectations (all industries and all sizes)" in the Tankan. They can be interpreted conceptually 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 firm's own 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–December 2022 surveys. As the output price DI has been available for a long period, even before 2014, it is used to estimate CPI inflation expectations before 2014. Unless otherwise noted, in this study, CPI inflation expectations and output price inflation expectations refer to one year ahead.

An important and unique aspect of this analysis is using data per industry and size from the Tankan. The Tankan has about 30 industry categories. There are also 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 trading partners and consumers. Therefore, if we aggregate only consumer-related industries corresponding to the latter, we obtain a series close to the movement of CPI inflation expectations. The analysis in this study focuses on this consumer-related industry.

We consider three ways to estimate CPI inflation expectations for all sizes and industries based on the output price DI by industry and size. The first method prepares various combinations from industry- and size-specific series of output price DIs and regresses CPI inflation expectations on those series sets to construct a relational expression. In addition to the combination above using only consumer-related industries, we consider the case where all industry and size series are included in the estimation equation.

The second method uses output price inflation expectations by industry and size and the output price DI. First, we perform a simple regression of each series of output price inflation expectations by industry and size on the output price DI for the same industry and size. Next, we regress CPI inflation expectations for all sizes and industries on a set of output price inflation expectations series. Using the two-step relational expression thus obtained, we develop a framework for estimating CPI inflation expectations from the output price DI. As the same firms respond to the output price DI and output price inflation expectations for each industry and size, we assume a reasonable correlation between these aggregate values. In this case, rather than regressing the CPI inflation expectations directly on the output price DI, obtaining a robust estimation formula may be possible by using the output price inflation expectations as a bridge and regressing it indirectly.

In the third method, instead of estimating an equation relating the CPI inflation expectations to the output price inflation expectations using the second method, the weight of individual items and services in the CPI is used. The estimated CPI inflation expectations are the weighted average of the estimated output price inflation expectations for each industry sector based on this weight. Fixing the weights will result in a robust, overall estimation framework. We examine various series sets as explanatory variables for the above three methods and find the best method based on in-sample and out-of-sample prediction errors.

The estimation framework proposed in this paper uses the relatively short-term relationship for 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 the one during 2014–2022. However, firms' views on prices may change over time. Moreover, as inflation dynamics may have changed from the 1990s to the 2020s, the resulting estimates of inflation expectations should be viewed with 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 not known. Further, as noted earlier, as there are no other long-run time series of inflation expectations for Japanese firms, comparisons are impossible. Instead, this study puts the long-run time series of estimated inflation expectations into a forecasting model of CPI inflation rates to test whether it has information on future inflation rates that cannot be explained by other macroeconomic variables such as foreign exchange rates and the output gap.[3]

Additionally, we conduct a comparative analysis of the differences in the estimated firms' inflation expectations from 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 for Japan over a sufficient sample period, mainly because obtaining a long-run time series of firms' inflation expectations is impossible. Therefore, this study uses the Consensus Forecast's one-year-ahead inflation expectations, obtained from Consensus Economic Inc., as the economists' inflation forecast and compares it to the estimated firms' inflation expectations.

This study's first contribution to the literature is to present long-run time series data on firms' inflation expectations in Japan. This is a necessary variable for various empirical analyses, and the ability to use price-setter firms' inflation expectations in empirical analyses is an important contribution. To some extent, the proposed estimation method is adapted to the data structure specific to the Tankan. However, it contributes to presenting a methodology in the context of the lack of data on firms' inflation expectations in other countries, as Coibion et al. (2020) highlight.

Studies on firms' inflation expectations in Japan include those of Uno et al. (2018), Inatsugu et al. (2019), and Kitamura and Tanaka (2019). They have presented additional empirical analysis results on the determinants of firms' inflation expectations and other factors. A further important contribution is to compare Japanese firms' inflation forecasts with economists' inflation expectations and examine the differences. As previous studies in this context, Nishiguchi et al. (2014), Kamada et al. (2015), Hori and Kawagoe (2015), Nakazono (2016), Hogen and Okuma (2018), Maruyama and Suganuma (2019), and Kikuchi and Nakazono (2021) analyze the inflation expectations of firms and other entities in Japan.

The remainder of this paper is structured as follows. Section 2 provides a detailed description of the Tankan series used in the estimation. Section 3 describes the framework for estimating firms' inflation expectations and presents the estimation results. Subsequently,

[3] 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.

Section 4 analyzes the time series property and predictive power of the estimated firms' inflation expectations. Finally, Section 5 concludes this paper.

2. Tankan index of inflation expectations

2-1. Available series

The Tankan is a survey of the actual corporate activity in Japan and 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 its 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. Consequently, some items have only been surveyed at certain times in the past or only relatively recently. The survey is currently 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 of "Outlook of Output Prices" and "Outlook of General Prices (i.e., CPI)" were launched in 2014. The former survey asks about companies' outlook for the sales price of its main products or the price of its main service offerings one, three, and five years from now, compared to the current level. The latter CPI inflation outlook asks for a one-year, three-year, and five-year outlook concerning the year-on-year change in the CPI. Responses are based on a multiple-choice format, with expectations in 5% bands (e.g., "around +10%" means the range from +7.5% to +12.4%) for the output price expectations and 1% bands ("around +2% means 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, when we speak of the Tankan's inflation expectations, we are generally referring to this average of outlook.

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.[4] One advantage of using this DI is the availability

[4] 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. Pinto et al. (2020) show that the utility of DIs derived from this kind of survey research for analyzing economic developments theoretically and empirically.

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 it is expected that changes up to three months ahead contain information about changes up to one year ahead.

In principle, it is possible to consider an estimation framework for CPI inflation expectations three or five years in the future. However, the greater the number of years' expectations, the less affinity they have with output price decisions, and the less accurate the estimation will be. For a one-year forecast, the DI movements generated from responses on 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 the DI is lower because recent shocks decay over time. Therefore, inflation expectations three and five years ahead are outside the scope of the main analysis. In Appendix B, we 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.[5] The one-year ahead CPI inflation expectations declined from approximately 1.5% in 2014, when the survey began, to the low 0% range in 2015–2016, remained at the same level, and declined further in late 2019. This 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 CPI inflation expectations at approximately 1% and was larger than the 2019 decline. The increase for 2021 and 2022 are greater than the CPI inflation expectations. During this period, the output price DI also moved similarly to the expectations series.

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

[5] The Tankan price outlook is answered, excluding the impact of consumption tax hikes and other systemic changes.

averaged by their weight in the CPI. Specifically, for the retailing, services for individual, 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 is considerably 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 of estimating inflation expectations

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

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

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

where y_t is the CPI inflation expectations for all firm sizes and industries for survey t, $\boldsymbol{x}_t = (x_{1t}, \ldots, x_{kt})$ is a vector of the selected k industry- and firm-size-specific output price DIs, and $\boldsymbol{b} = (b_1, \ldots, b_k)'$ is their regression coefficient. Using $\hat{c}$ and $\widehat{\boldsymbol{b}}$, estimated using the least squares method, the CPI inflation expectations before 2013 is 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 estimation. In this case, the Lasso regression method is used to estimate c and $\boldsymbol{b}$, which minimizes the following equation:

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

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

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

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

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

(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, the vector 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 the CPI inflation expectations before 2013 in 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 above 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 estimation.

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

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

We consider a method where the second estimation equation in Estimation equation 2 is modified as in the following equation:

(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 the individual prices corresponding to industry i, as w_i. For example, if we use two industries, retailing ($i = 1$) and services for individual ($i = 2$), 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, respectively, sum to one. We calculate the 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 $(z_{1t}, \ldots, z_{kt})$ 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 to the Estimation equation 2.

The weights (w_i) are those of the 2020 base CPI relative to 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 the 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. Sets of variables are classified into three categories. The first approach uses a single series, an all-firm-size series for all industries (Set 1), for retailing only (Set 2), and the 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 types of estimation equations: (1) One-step direct regression and (2) Two-step indirect regression. For Sets 4–6, we apply a third type of regression, (3) two-step weighted regression. For Sets 7 and 8, as it is difficult to evaluate CPI weights tied to each industry sector, we apply only two types of regression: (1) one-stage direct regression and (2) two-stage indirect regression. For these sets we use the Lasso regression method due to many explanatory variables.

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

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 observed values. The estimation period spans 36 survey cycles, from the March 2014–December 2022 surveys.

We next compare out-of-sample predictability. First, we create estimates using the sample for the March 2014–December 2017 surveys. The resulting estimates forecast 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 the March 2018 survey data and again produce estimates, similarly projecting CPI inflation expectations one period ahead of the June 2018 survey. This is repeated up to the 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 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 variable Set 1, featuring the series of all firm sizes and industries, is used to provide explanatory variables. 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 the simpler model focusing on consumer industries in Sets 2–6 is superior. Although Sets 7 and 8 are estimated by the Lasso regression method, and the series of several industries including consumption-related industries are statistically significant, the estimated coefficient for consumption-related industries are shrunk to some extent. Therefore, it is considered that the in-sample fit deteriorates. In-sample fit is important when creating inflation forecasts, and we do not use Sets 7 and 8. We use sets 1–6 as candidates for comparison for the following out-of-sample forecasts.

Table 3 presents the RMSE of out-of-sample predictability. As with the in-sample, the RMSE is smaller when taking the consumer-related industries in Sets 2–6 as explanatory variables than when using variable Set 1. In Sets 2 and 3, featuring only one explanatory variable, the one-stage direct estimation has a smaller RMSE than the two-stage indirect estimation. Conversely, in Sets 4–6, featuring multiple explanatory variables, the two-stage indirect estimation has a smaller RMSE. This indicates that the supplemental use of data on output price expectations improves forecast accuracy more than using 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 suggests that a stable forecast can be produced by fixing each industry's weights to values consistent with the CPI. Among all the variable sets and estimation equations, the two-stage weighted estimation in Set 6 produces the smallest RMSE. This result is robust even when changing the beginning of the forecast period. Thus, we employ the long-run time series of inflation expectations estimated using this method to conduct our analysis.

It is of interest that 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 quite reasonable as these industries constitute the CPI. One may argue that additional information on corporate prices upstream in the production process may better fit inflation expectations. However, the model incorporating each industry has a larger in-sample RMSE as explained above. Even when the forecast accuracy is calculated by adding one other industry to the consumer-related industries, we do not find any set where the out-of-sample RMSE is smaller than for consumer-related industries alone. These results indicate that the relationship between corporate and consumer prices may have changed over time or is not 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 estimation using the input price DI instead of the output price DI or accompanying output price DI. Nonetheless, the RMSE is not reliably smaller than for variable Set 6. This result suggests that information about input prices that can affect inflation expectations is mostly 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 estimated inflation expectations. The shadowed ranges denote 95% confidence intervals calculated using the Monte Carlo method. A comparison with the (observed) CPI inflation expectation data presented in Figure 3 shows that the estimates fit the observed values reasonably well but that there is a divergence with observations outside the 95% confidence interval for the March–December 2014 survey. Our long-run time series of inflation expectations presented are estimated values up to the December 2013 survey and observed values as of the March 2014 survey. Owing to the divergence between the December 2013 and March 2014 survey observations, it is inappropriate to connect them as is.

We consider connecting estimated values up to the December 2013 survey with the observed values from the March 2014 survey, minimizing damage 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 formulization that minimizes 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 a somewhat ad-hoc approach, we discount the difference between the estimate and observed values in the March 2014 survey backward at a set rate from December 2013 and add to the estimate creating a connection. We take r as this discount rate and g as the observed value less than the estimated value in the March 2014 survey. Taking the estimated inflation expectation value as $\hat{y}_t$ and $\hat{\hat{y}}_t$ as the value corrected for this connection, we correct the estimate values before December 2013 using the following equation:

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

where T denotes the March 2014 survey—the range of correction decays moving backward through the sample period, from gr for the December 2013 estimate value, gr^2 for September 2014, to gr^3 for June 2014.

Regarding 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. Then, we obtain $r = 0.852$. We correct the estimate values based on this r value to connect them to the observed values from the March 2014 survey. This correction is preferable as 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 have hovered approximately 0% since the late 1990s. This 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.

A comparison of the actual CPI inflation rate (the total excluding fresh food, energy, and special factors; year-on-year; the same holds below)[6] and the firms' inflation expectations, shown in Figure 4, suggests that movements in inflation expectations yield information useful for predicting the actual inflation rate. The dramatic decline in inflation in the early 1990s and the increases in inflation in the late 2000s and 2013–2015 show that inflation expectations anticipate 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 a divergence. In 2010, in particular, in the aftermath of the global financial crisis, inflation expectations fell only to about -0.5%, while the actual figure fell to nearly -1.5%. This may be due to downward rigidity in inflation expectations, as noted by Gorodnichenko and Sergeyev (2021), and this not-significantly-negative characteristic may also manifest in the inflation expectations estimated in this study.

Figure 4 compares the year-ahead inflation expectation in the Consensus, an economists' forecast, with the inflation expectations we estimate. While similar on average, closer scrutiny reveals important differences in their relation to the actual inflation rate. Economists' forecasts are characteristically higher in the first half of 1990, while corporate inflation expectations are correspondingly higher in 2022. Turning to the actual figures, and as noted above, firms' inflation expectations are more preemptive of 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 may yield greater information about future inflation rates than economists' forecasts.

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

We next analyze the role of inflation expectations in the CPI inflation rate forecast

[6] 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.

equation. Coibion et al. (2018) examine whether, in addition to standard macroeconomic variables such as the output gap, inflation expectations hold information that complements the explanatory power provided by those variables. We examine whether the firms' inflation expectations contain information that complements the explanatory power of those economic variables. 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 the firms' inflation expectation is added. The estimation period is December 1990 survey to December 2021 survey. The 2022 sample is a period close to the end of the output gap estimate, and since there is a possibility that it will be revised to some extent in the future, the end of estimation period is set to 2021.

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

Finally, we verify whether the firms' inflation expectation improves the accuracy of the 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. Subsequently, we add the March 2015 survey to the data and use this to project the inflation rate for the June 2015 survey. We iteratively calculate values to obtain predicted values up to the December 2021 survey. Changing the lag of the explanatory variable from one quarter to two quarters, we calculate expected values two quarters forward. In other words, we use data for the period 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 three or four quarters ahead. We repeat these forecasts, adding one-quarter of data at a time until forecast values are available for the December 2019 survey, up to the point at which the COVID-19 pandemic manifests, which produces 20 quarters forecasts. We validate this forecast analysis with and without the inclusion of firms' inflation expectations.[7]

[7] 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.

Table 7 presents the RMSE of the difference between the forecast and actual CPI inflation values. For 1–4 quarters ahead, the RMSE is smaller, and the forecast accuracy is higher when using the firms' inflation expectations. Testing whether the difference in RMSE is statistically different from zero using the Model Confidence Set (MCS) method proposed by Hansen et al. (2011), we find that using the firms' inflation forecast 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 evidently improves the accuracy of one-year-ahead forecasts.[8]

We also calculate forecast accuracy using economists' forecasts instead of firms' inflation expectations. We find that the firms' inflation expectations improve forecast accuracy more than the economists' forecasts for all 1–4 quarters ahead, as presented 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 ahead is statistically significant. The same results for the above forecast analysis are obtained even when extending the measurement period beyond 2020. This indicates that the firms' inflation expectations estimated in this study are statistically 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 important to determine the inflation rate.

5. Concluding remarks

This study uses the output price DI in 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 are obtained using the output price DI in combination with the inflation outlook for the company's output prices. The estimated inflation expectations contain information not available in other standard macroeconomic variables able to improve the forecasting accuracy of a simple inflation forecasting model.

It is challenging to discuss whether the presented inflation expectations is a good series of firms' inflation expectations because the true inflation forecast is unknown. In such as case, using multiple measures of inflation expectations for comparison is advisable. Given

[8] 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.

the extremely limited availability of such time series data, the series presented in this study can increase the number of inflation expectations series available for reference, expand the breadth of analysis, and confirm the robustness of such analysis.

One caveat concerning our framework is that all relational equations are assumed to be linear. Although a nonlinear relationship can exist between two variables that construct a relational equation, only 32 quarterly counts exist for March 2014–December 2021. Therefore, the sample is insufficiently large to determine a nonlinear 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 from -100 to 100. While Pinto et al. (2020) show that a DI constructed in this manner can precisely approximate the average of responses to inflation expectations, the theoretical relationship between the distribution of respondents to the DI items behind the DI and the average of responses to inflation expectations is beyond the scope of this study.

This study estimates short-term, one-year-ahead inflation expectations, but 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 forecast output price DI. Another caveat is that series created using only short-term information do not adequately capture inflation expectations specific to medium- to long-term durations due to, for example, inflation targets. It is important to continue uninterrupted survey research, such as the Tankan survey, for medium- to long-term firms' inflation expectations data.[9]

[9] 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, and it is challenging to use the same framework to estimate medium- to long-term inflation expectations such as those three or five years hence. However, medium- to long-term inflation expectations are important when empirically analyzing inflation dynamics and policy effects. As long-run time series data candidates are limited for Japan, estimating firms' medium- to long-term inflation expectations using the Tankan DI significantly contributes to the 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 forecast, and the Tankan three- and five-year ahead inflation expectations. As we only have the output price DI before 2013, supplementing it with information on the medium- and long-term inflation expectations are 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 next five years counts as the medium- to the long-term inflation expectations. This study uses this forward rate as the inflation expectations for three years ahead, midway between 1–5 years.

As the 2003 survey of the ASCB was conducted in January 2004, it is considered at almost the same time as the December 2003 survey of the Tankan for estimation purposes. As it is an annual survey, we use linear interpolation to create quarterly series. Moreover, as seen from the indirect method of calculating inflation expectations discussed earlier, this series of inflation expectations correspond to the GDP deflator forecast, which is expected to diverge from the CPI inflation expectations. Therefore, we adjust the level such 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 forecast 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 inflation expectations three years ahead 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 has turned upwards afterwards.

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:

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

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

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

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

$$\cdots$$

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

Thus, we obtain

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

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 rate that reflects firms' perception of the inflation rate over the past year from the actual output price DI in the Tankan and fit 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 of firms emphasizing 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 forecast for h periods ahead as $\pi_{t+h|t}$. As the Tankan inflation expectations and 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 $i = 1, \dots, 4$; $\pi_{t+4|t}$ 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. Because there is no Tankan inflation expectations series before the fourth quarter of 2013, the equation comprises three observation equations: two for perceived inflation rate and the estimate inflation expectations one year ahead, plus the three-year ahead inflation expectations from the ASCB. The Tankan inflation forecast becomes available in the first quarter of 2014, resulting in a four-observation equation. The variance of the error term ϵ_{it} in the Tankan inflation forecast 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 the inflation rate dynamics because the data series are monthly and available over considerably long periods. However, as the Tankan data are quarterly, and the inflation expectations series cover only a short period, a simple AR(1) model is assumed to conserve parameters.

We calculate the perceived inflation rate using the fact that the actual consumer-related industry output price DI series weighted by 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 simultaneously is high, 0.753 for the period from the third quarter of 1991 to the fourth quarter of 2022. Further, as the output price DI series is an evaluation for the most recent three months, a correlation coefficient becomes higher, namely 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, a linear relationship between the two can be calculated by regressing the inflation rate on the output price DI. As 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 negative territory in 2000, but perceived inflation rate remained at approximately 0%. Moreover, while actual inflation rose to approximately 0% in 2003, perceived inflation rate was been as low as -1%.

Models (A3)–(A5) are estimated using the maximum likelihood method with Kalman filter and 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, for which the perceived inflation rate are 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. The 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. Related to this, the characteristics of the term structure of inflation expectations can be exhibited 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); they estimate inflation expectation curves from data on various inflation expectations in Japan.

Appendix Figure 5 shows estimated 5-year ahead inflation expectations and its 95% confidence interval. The observed values (actual Tankan values) fall within this interval, except for a small portion of the period in 2021, indicating the estimate to be a good fit. From approximately 1.5% circa 1992, 5-year ahead inflation expectations continued intermittently, declining to approximately 1% circa 1995 and approximately 0.5% circa 2000. Subsequently, they increased around 2012, slightly above 1.5% in 2014. Appendix Figure 6 shows the estimated values for the trend inflation, and its 95% confidence interval shows almost the same movements as the 5-year ahead inflation expectations. In prior studies, the 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 movements are broadly similar throughout the sample period.

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

Appendix Figure 7(1) shows estimated firms' five-year forward inflation expectations and economists' five-year forward inflation expectations, which is from Consensus Forecasts. During the 1990s and 2000s, firms' inflation expectations were lower than economists' expectations—the difference between the two averages was approximately 0.5 percentage points. In the late 1990s and 2000s, economists' inflation expectations rose to approximately 1.5%, but no such movement was seen in firms' inflation expectations. Appendix Figure 7(2) shows estimated firms' trend inflation and economists' 6- to 10-year inflation expectations; these show similar differences from the 5-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 of this paper to identify differences in forecast accuracy in the inflation forecasting models. Specifically, RMSEs were calculated 1–8 quarters ahead of inflation expectations from the first quarter of 2015 to the fourth quarter of 2019. Note that the series estimated using the method above from the all-period data was uniformly used for firms' inflation expectations. In other words, the forecast is not based on counts created from data available in real-time, which is a caveat in this forecast analysis.

Appendix Table 1 presents the results, showing little difference in forecast accuracy for the first five quarters. Meanwhile, forecast accuracy for the 6th–8th quarters is higher when firms' inflation expectations are used. As in the main study, statistical tests are conducted on these differences in predictive accuracy, but they are 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 a future path of the inflation rate as economists' inflation expectations and may be useful when analyzing inflation rates and policy effects.

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

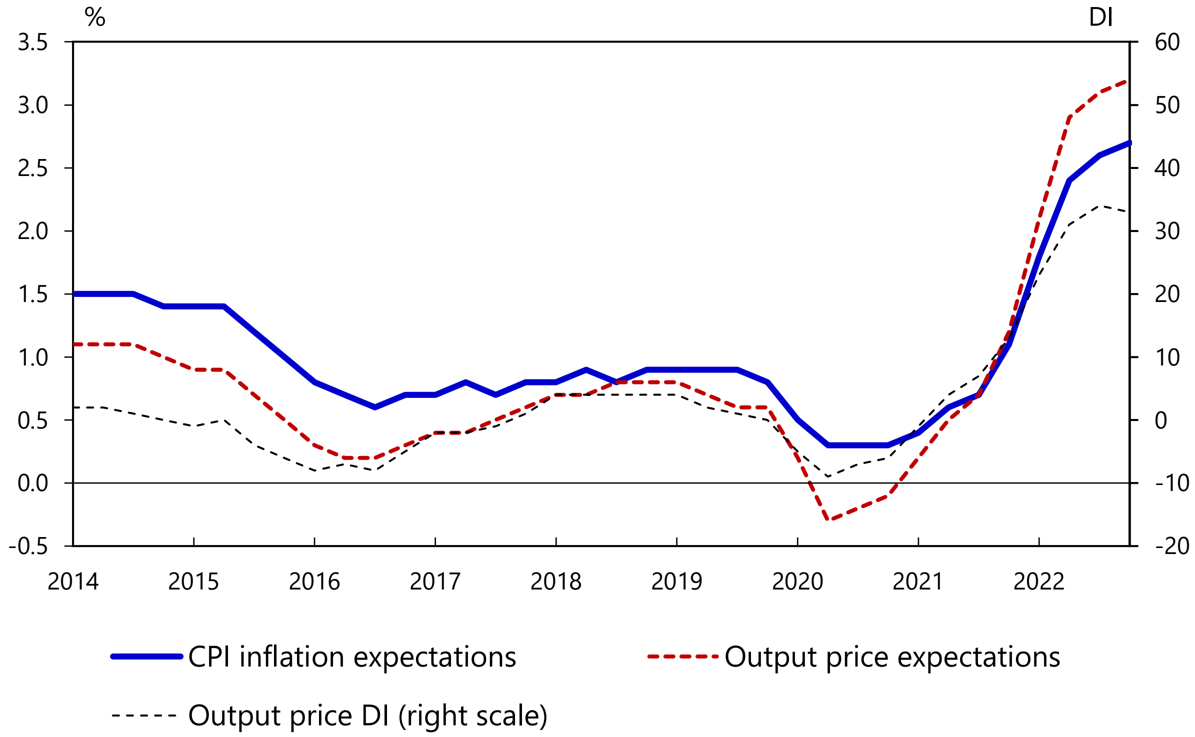
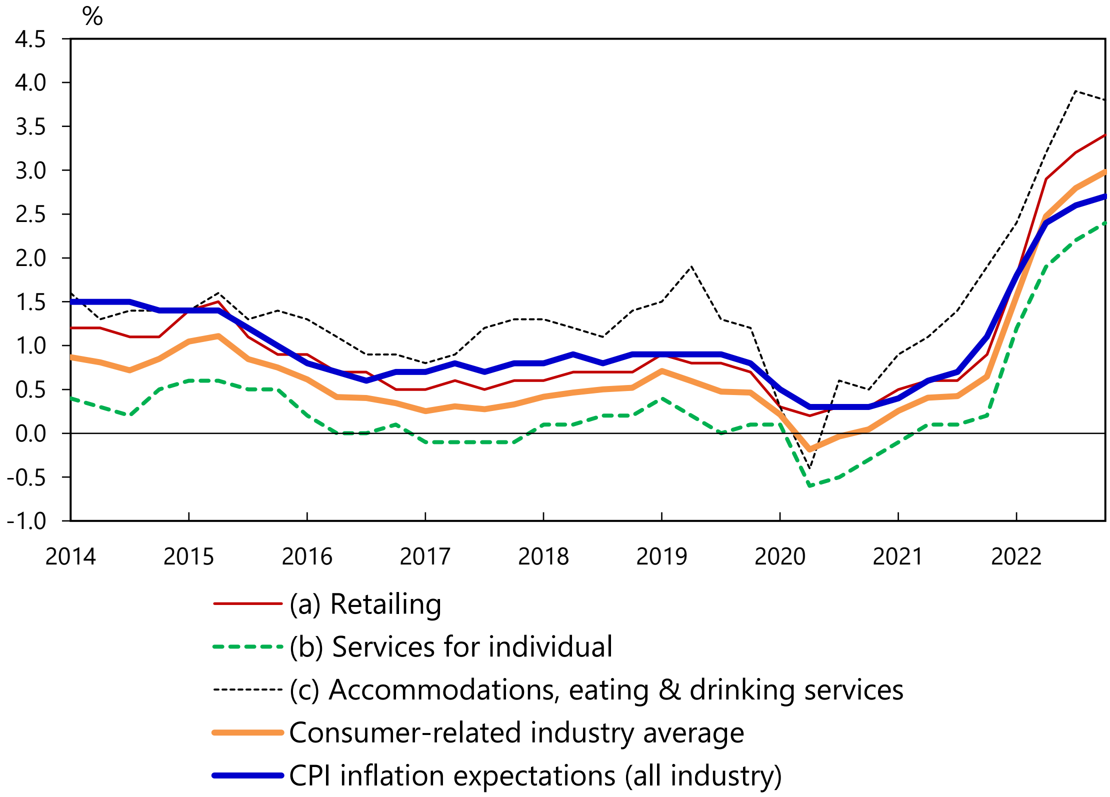
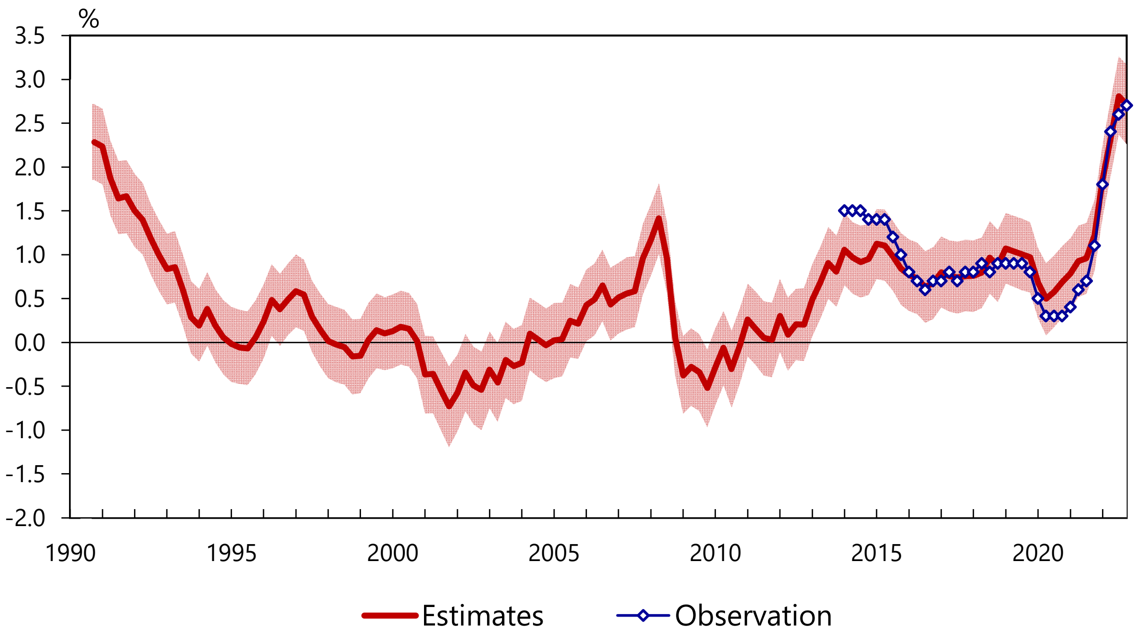


Figure 2. Tankan consumer-related industry output price expectations (all firm sizes, one year ahead)



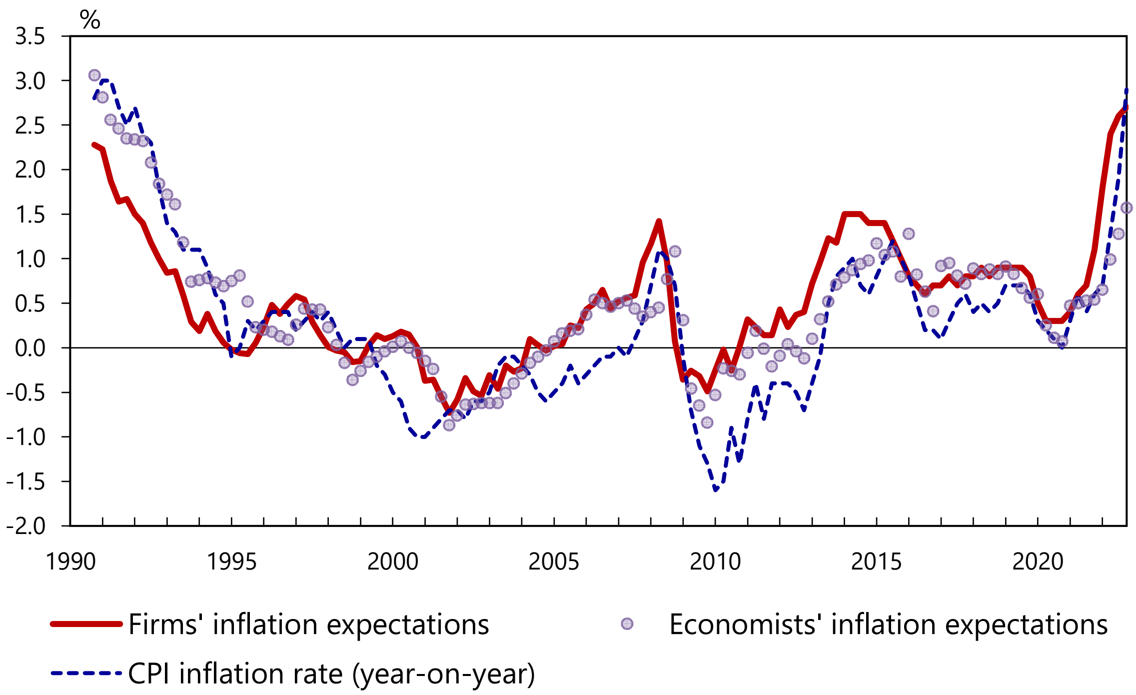
Note: Consumer-related industries are weighted averages of (a) through (c), weighted according to their weight in the CPI (see the text for details).

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



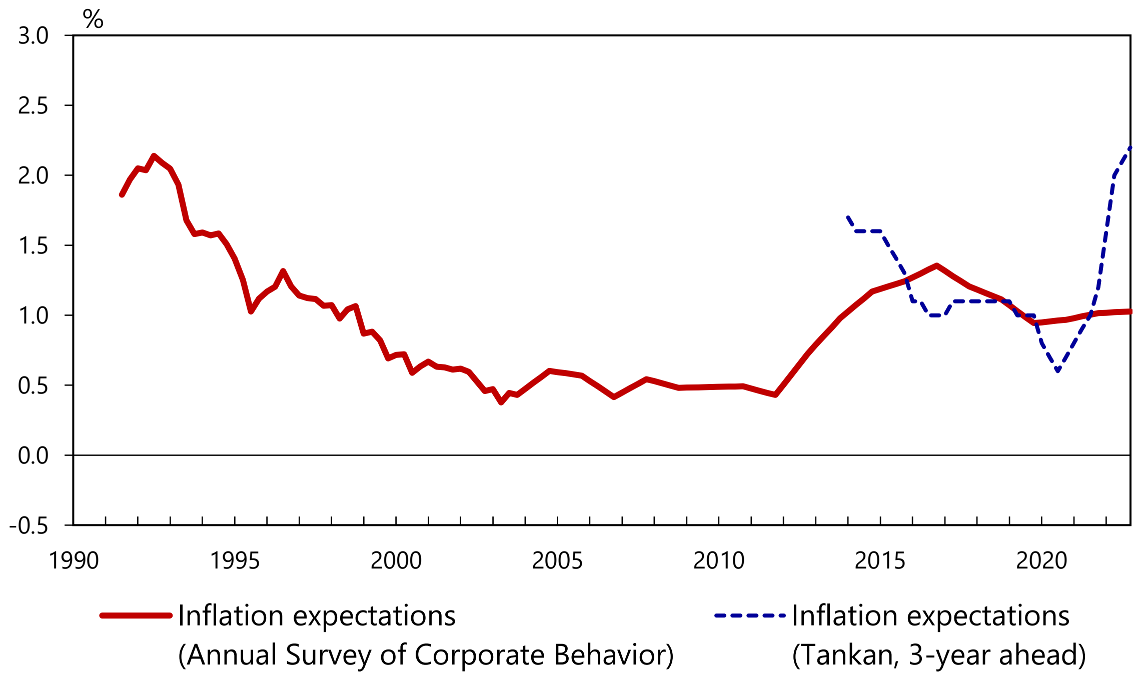
Note: The shadowed ranges show the 95% confidence interval for the estimates.

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

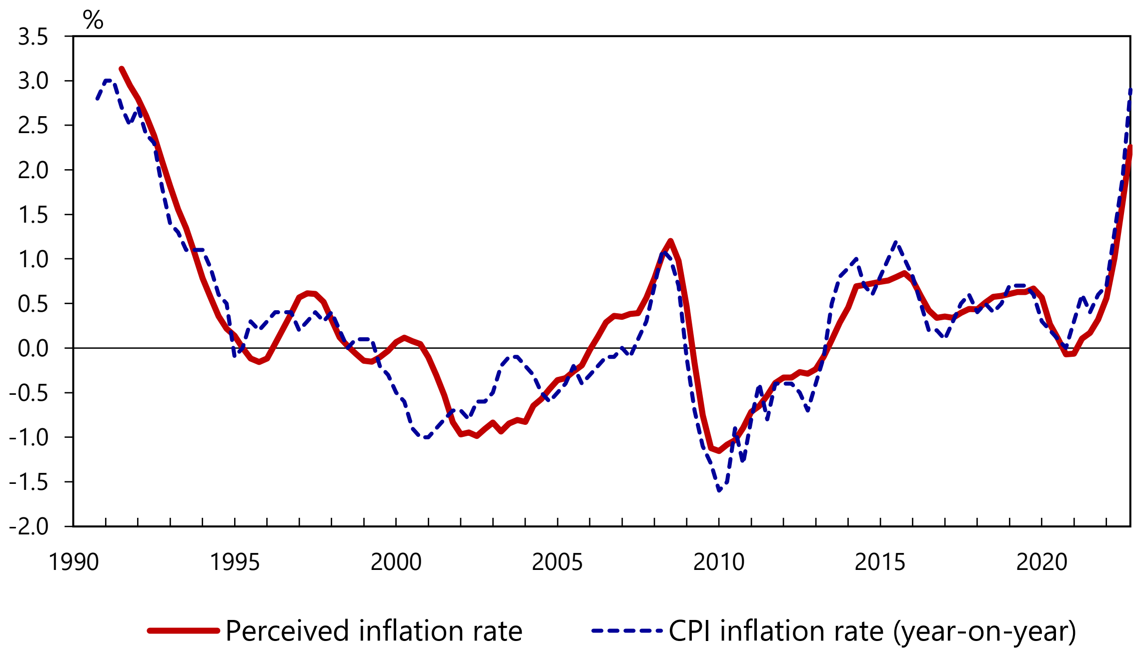


Note: The CPI inflation rate is the total, excluding fresh food, energy, and special factors (see the text for details). The economists' inflation forecast is the one-year-ahead Consensus Forecasts.

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

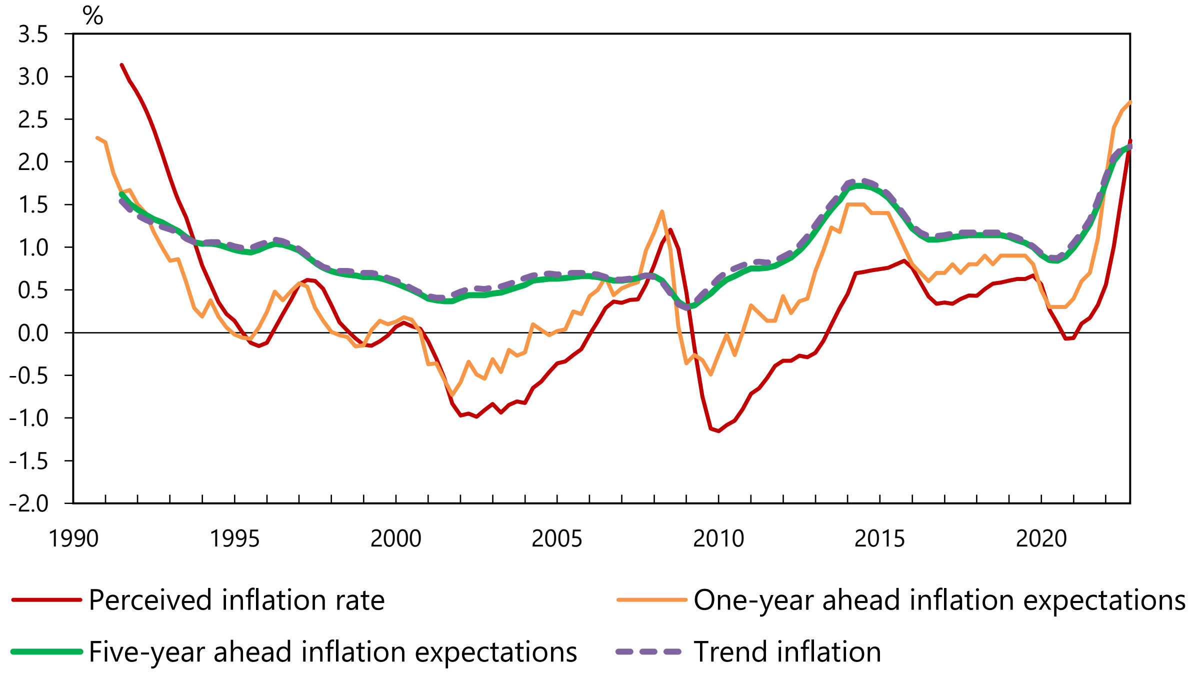


Appendix Figure 2. Estimated perceived inflation rate

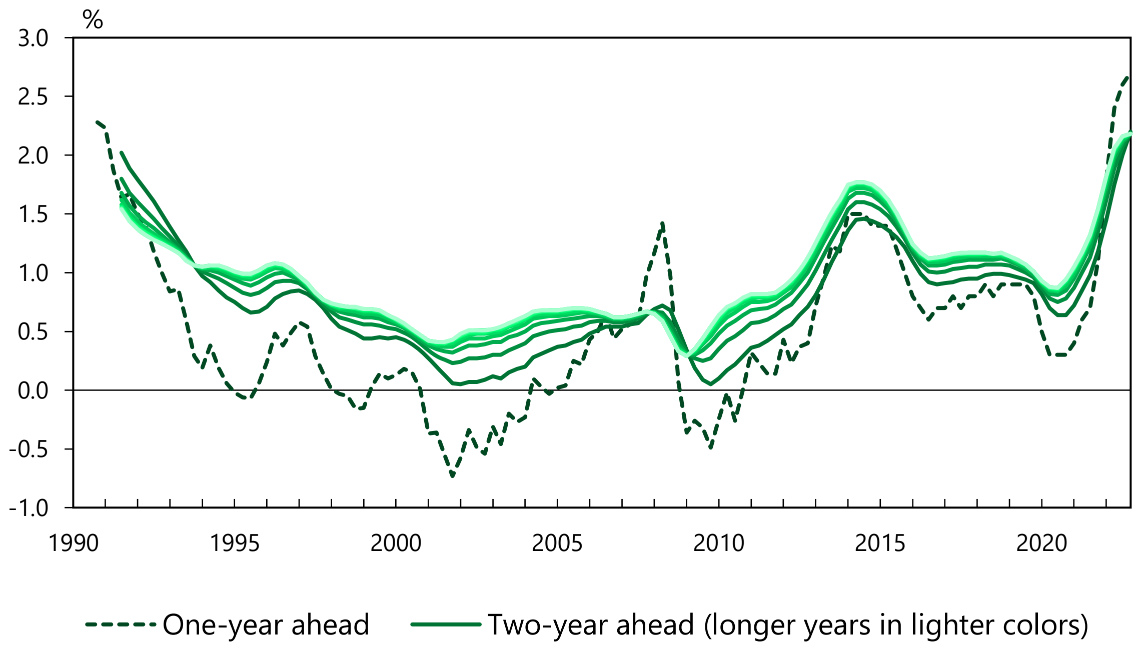


Note: The CPI inflation rate is the total, excluding fresh food, energy, and special factors (see the text for details).

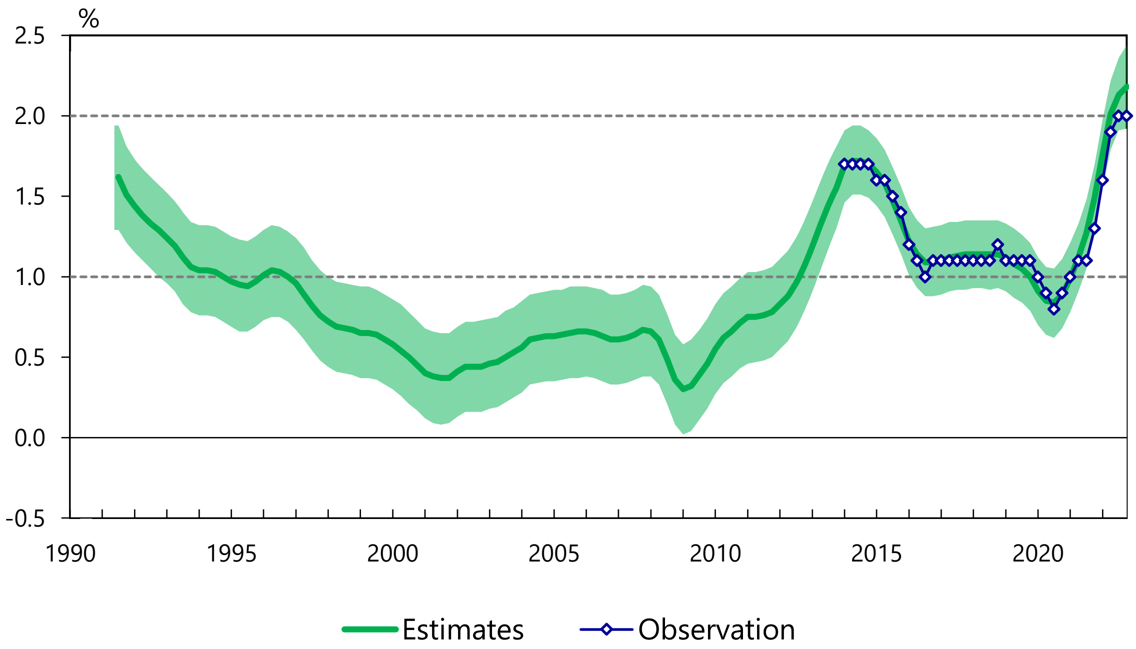
Appendix Figure 3. Estimates of firms' inflation expectations



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

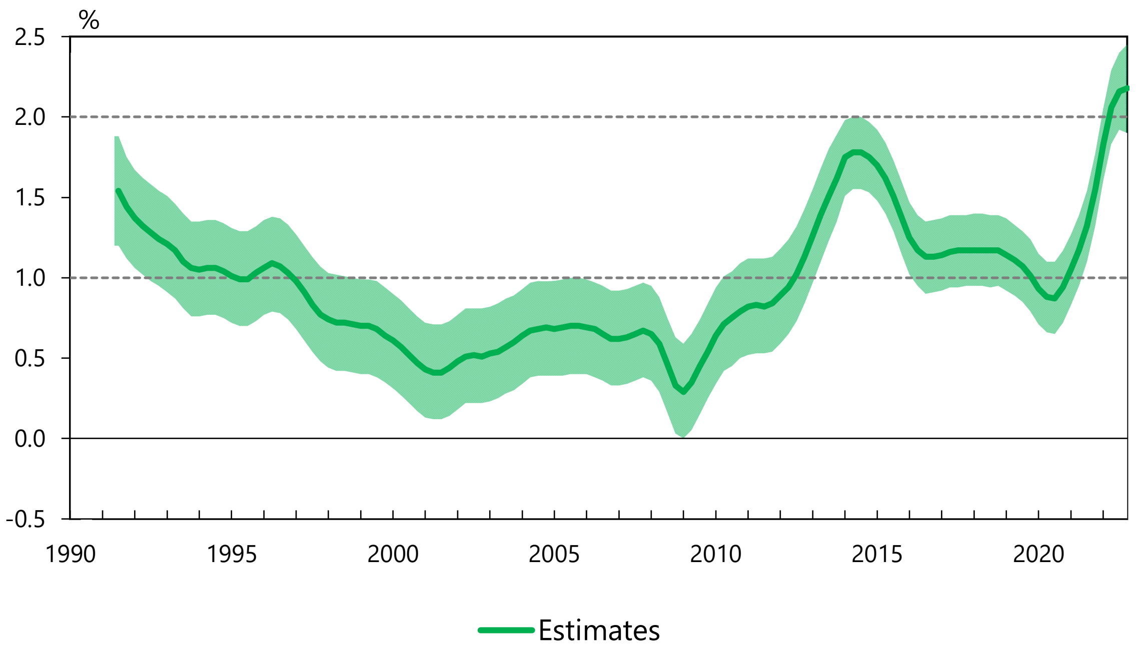


Appendix Figure 5. Estimated and observed firms' inflation expectations (5 years ahead)



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

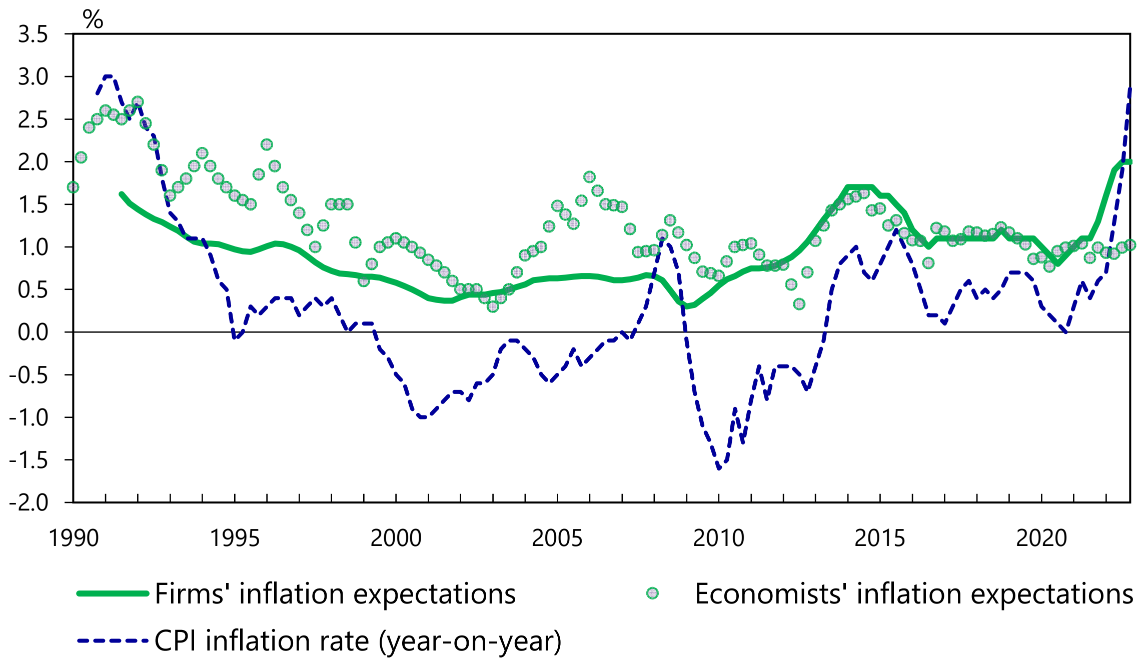
Appendix Figure 6. Estimates of firms' trend inflation



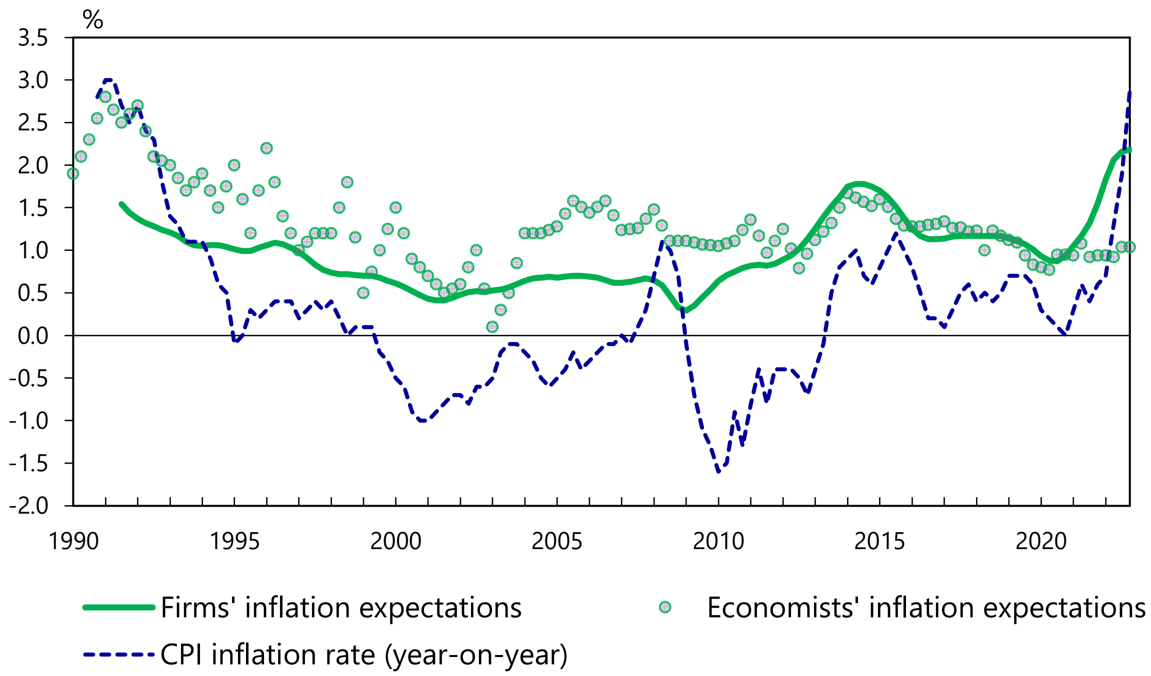
Note: The shadowed ranges show the 95% confidence interval for the estimates.

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 forecasts 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 the 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)		
CPI inflation rate does not cause inflation expectations	9.086	0.000
Inflation expectations do not cause CPI inflation rate	0.479	0.751
a. Economists' inflation expectations (one year ahead)		
CPI inflation rate does not cause inflation expectations	6.157	0.000
Inflation expectations do not cause CPI inflation rate	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 the text for details). The economists' inflation expectations are 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 the 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 error. ***, **, 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. * indicates that the difference from (1) for (2) and (2) for (3) is statistically significant at the 10% level.

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.