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Uncertainty in the Formation of Inflation Expectations in Japan: An Analysis Using the Macroeconomic Model Q-JEM

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Abstract

This paper examines the formation mechanism of medium- to long-term inflation expectations in Japan using the Bank of Japan's large-scale macroeconomic model, the Quarterly Japanese Economic Model (Q-JEM), from the perspective of the model's past forecast accuracy and its assessment of future uncertainty. We compare the forecast accuracy of various specifications of the inflation expectations function in the model, and find that specifications that take into account the mechanism of adaptive expectations, which is influenced by past actual values of inflation, provided relatively high forecast accuracy on average since 2013. However, the relative forecast accuracy between different specifications varied from phase to phase, suggesting a large uncertainty in the expectations formation mechanism itself. We also assess the future uncertainty of inflation expectations based on the model's past forecast errors. Under the assumption of adaptive expectations mechanism, inflation expectations are more likely to rise when the recent actual inflation is higher.

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1. Introduction

For about 25 years since the late 1990s, nominal interest rates in Japan have generally remained near zero and faced an effective lower bound. Even under such circumstances, it has been widely pointed out that demand for capital investment and consumer spending can be stimulated through lower real interest rates if people's inflation expectations can be raised.[1] In light of these points, it was envisioned that the "expectation channel" would play an important role in the monetary policy transmission under the "price stability target" of 2 percent and the "quantitative and qualitative monetary easing (QQE)," which were introduced by the Bank of Japan in 2013. In fact, people's inflation expectations rose in 2013, and in this sense, the above channel did play a role. Since then, however, inflation expectations have not risen as much as originally envisioned. With regard to this background, the Bank's "Comprehensive Assessment" in 2016 and "Assessment for Further Effective and Sustainable Monetary Easing" in 2021 pointed out that the mechanism of adaptive expectations, which is influenced by the past actual values of inflation, had played a larger role in Japan than in other advanced economies, and that people's mindset and behavior based on the assumption that prices would not increase easily had become deeply entrenched as norms under the prolonged deflation and low inflation (Bank of Japan 2016, 2021). Various analyses are underway regarding the specific background of such norms in the "Review of Monetary Policy from a Broad Perspective (Broad Perspective Review)" that the Bank began in 2023.

As part of the "Broad Perspective Review," this paper examines the formation mechanism of medium- to long-term inflation expectations in Japan using the Bank's large-scale macroeconomic model, the Quarterly Japanese Economic Model (Q-JEM), which has been used for over 15 years since the late 2000s for forecasting the economy and inflation, assessing risks, and evaluating the effects of monetary policy.[2] Q-JEM has been based, to no small extent, on theoretical and empirical studies conducted in academia on the formation mechanism of firms' and households' inflation expectations. However, especially since 2013, when the inflation environment in Japan including the monetary policy framework changed drastically, Q-JEM had to be operated through a process of trial and error without waiting for the results of academic studies. In this paper, while mentioning some of the trial and error processes, we look back on several phases since 2013 and also explore future implications, from the perspective of what model specifications were desirable in practice for forecasting inflation and how the forecast

[1] Krugman (1998) was one of the papers that made this point early on.

[2] For Q-JEM, see Fukunaga et al. (2011) and Hirakata et al. (2019).

uncertainty should be assessed. Other central banks also consider the formation mechanisms of inflation expectations in their large-scale macroeconomic models similar to Q-JEM (e.g., the FRB/US model of the Federal Reserve Board [FRB] and the ECB-BASE model of the European Central Bank [ECB]), but unlike in Q-JEM, they do not seem to have experienced such a process of trial and error in the specifications of inflation expectations function in their models, partly because medium- to long-term inflation expectations in their countries have remained stable.[3] In this respect, the uniqueness of our analysis in this paper is based on the modeling practices of the Bank of Japan staff taking into account Japan's unique experience of changing inflation environment.[4]

The main results from the analysis in this paper are as follows. First, among various specifications of the inflation expectations function in Q-JEM, specifications that take into account the mechanism of adaptive expectations, which is influenced by past actual values of inflation, provided relatively high forecast accuracy on average since 2013. However, the relative forecast accuracy between different specifications varied from phase to phase, and even a complex specification that takes into account the possibility that the weight of adaptive expectations may change over time provided little improvement in forecast accuracy compared to the relatively simple specification used by other central banks. These results generally suggest a large uncertainty in the formation mechanism of Japanese people's inflation expectations itself, although in recent years the forecast performances with all these specifications are improving as medium- to long-term inflation expectations are steadily rising toward 2 percent. Second, under the assumption of adaptive expectations mechanism in Q-JEM, the responses of consumer price inflation and medium- to long-term inflation expectations to shocks to commodity prices and foreign exchange rates can vary depending on the timing and direction of the shocks. Simulations on the future uncertainty of medium- to long-term inflation expectations based on the model's past forecast errors show that inflation expectations are more likely to rise in a high inflation period when the recent actual inflation is higher than

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[3] For the FRB/US model, see Brayton, Laubach, and Reifschneider (2014) and Laforte (2018), among others. For the ECB-BASE model, see Angelini et al. (2019). Simulations on medium- to long-term inflation expectations using the ECB-BASE model are conducted in the ECB's "Strategy Review" (Baumann et al. 2021).

[4] An example of analysis relatively close to this paper is Anand, Hong, and Hul (2019), which assesses the likelihood of achieving the Bank of Japan's 2 percent inflation target based on an inflation expectations function that depends on the credibility of the central bank and other factors, using the IMF's Quarterly Projection Model for Japan.

in a low inflation period, even if the levels of inflation expectations at the start of the simulations are almost the same between the two periods.

The analysis in this paper is closely related to the following three papers in the "Broad Perspective Review."[5] First, Osada and Nakazawa (2024) discuss various measures of inflation expectations in Japan and then construct composite indicators based on the term structure and forecasting power of individual measures. The medium- to long-term inflation expectations used in this paper is their "composite index" of 10-year-ahead inflation expectations. Second, Kaihatsu, Nakano, and Yamamoto (2024) examine the impact of shifts in long-term inflation expectations on economic activity and price dynamics in Japan using a time-varying parameter vector autoregressive (TVP-VAR) model, in which the same "composite index" of 10-year ahead inflation expectations is included as an endogenous variable. Their model is positioned as a complementary approach to our analysis in that their model does not specify the formation mechanism of inflation expectations and fits to the data in a more flexible manner. Third, Haba et al. (2025) use the same version of Q-JEM as in this paper to quantitatively assess the effects of the Bank of Japan's various unconventional monetary policy measures on the economic activity and prices since 2013, including their effects through higher inflation expectations. What they estimate are "counterfactual paths" of inflation expectations and other variables in the absence of monetary easing,[6] and thus their analysis reflects different motivations from ours in this paper that examines the actual formation mechanism of inflation expectations and assesses the model's forecast accuracy.

The remainder of this paper is organized as follows. In Section 2, we survey theoretical and empirical studies on the formation mechanism of inflation expectations, focusing on studies closely related to our analysis. Based on the literature survey, Section 3 discusses some specifications of the inflation expectations function in Q-JEM by comparing their forecast accuracy since 2013. In Section 4, under the assumption of adaptive expectations mechanism, we run simulations using Q-JEM on the responses of inflation expectations

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[5] In addition to these three papers, Fukunaga, Hogen, and Ueno (2024) provide an overview of economic activity and prices in Japan over the past 25 years since the 1990s, and also consider the possibility that deflationary expectations became entrenched in a self-fulfilling manner (deflationary equilibrium) and the relationship between inflation expectations and growth expectations. Furukawa et al. (2024) studies the causes of the "zero-inflation norm" using menu cost models.

[6] Haba et al. (2025) estimate a simple inflation expectations function that depends on a trend inflation and a few other variables using the data up to 2012, prior to the introduction of QQE, in order to estimate a counterfactual path of medium- to long-term inflation expectations in the absence of monetary easing.

to exogenous shocks and on the future uncertainty of inflation expectations based on the model's past forecast errors. Session 5 concludes.

2. Theoretical and Empirical Studies on the Formation of Inflation Expectations

This section briefly surveys previous studies on the formation mechanism of inflation expectations, mainly on empirical studies using Japanese data.

First, looking back on the theory, we recognize that the idea of adaptive expectations, which assumes that people's inflation expectations depend on past actual inflation, was incorporated into economic theory more than 100 years ago (Fisher 1911). Then, after the "rational expectations revolution" about 50 years ago (e.g., Lucas 1972), the standard assumption in modern macroeconomic textbook models is that economic agents form expectations rationally using all the information available at the time (full information and rational expectations).[7] However, this assumption is often rejected in empirical studies (e.g., Coibion, Gorodnichenko, and Kamdar 2018). Assumptions more consistent with the data include the "sticky information" hypothesis (e.g., Mankiw and Reis 2002; Carroll 2003), the "noisy information" hypothesis (e.g., Woodford 2003), and the "rational inattention" hypothesis (e.g., Sims 2003; Maćkowiak and Wiederholt 2009), all of which assume that information is incomplete in the sense that economic agents do not have accurate or timely information. For example, the sticky information hypothesis assumes that economic agents do not necessarily update their information sets every period because of the cost of acquiring information, but rather use their old information sets to form expectations. Other theories of imperfect information include the "adaptive learning" hypothesis (Evans and Honkapohja 1999, 2001), which assumes that economic agents do not have a precise understanding of the economic structure in the first place.[8]

Although attempts have been made to test which of these hypotheses are more consistent with the data, no consensus has been reached. To highlight a few analyses that test these hypotheses using Japanese data, for example, Kikuchi and Nakazono (2023), using household-level micro-data, find that consumers do not frequently update their information sets on inflation and exhibit behavior similar to the sticky information hypothesis. Uno, Naganuma, and Hara (2018), using firm-level micro-data from the

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[7] As pointed out by Yoshikawa (2022) and others, what "rationally" formed expectations mean depends on the model structure and stochastic disturbances. Under certain conditions, adaptive expectations can also be rational expectations.

[8] Applying the framework of the adaptive learning hypothesis, Hogen and Okuma (2025) estimate the degree of anchoring of long-term inflation expectations using Japanese data.

Tankan survey, find that firms' inflation expectations are in line with predictions of the sticky information hypothesis. Kaihatsu and Shiraki (2016), using other survey data, find that the responses of firms' inflation expectations to monetary policy shocks are consistent with the rational inattention hypothesis. Inatsugu, Kitamura, and Matsuda (2019), from the analysis using the Tankan survey data, conclude that Japanese firms form their inflation expectations in a complex manner that may be consistent with noisy information, sticky information, and rational inattention hypotheses and cannot be described by a single hypothesis. Kitamura and Tanaka (2019) obtain similar results from a small-scale macroeconomic model.

In relation to monetary policy, it has been pointed out that the formation of inflation expectations in Japan has been largely adaptive, no matter about the correspondence with the above hypotheses, which lead to weak and insufficient anchoring of inflation expectations to the central bank's inflation target compared to other countries (e.g., Ehrmann 2015; Nishino et al. 2016). It has also been pointed out that the mechanism of adaptive inflation expectations is influenced not only by recent but also by historical long-term inflation experience (e.g., Diamond, Watanabe, and Watanabe 2020). On the other hand, many studies find that the introduction of the "price stability target" of 2 percent in 2013 has strengthened, albeit insufficiently, the anchoring of inflation expectations to some extent (Fukuda and Soma 2019; Kamada, Nakajima, and Nishiguchi 2015; to little extent in Fujiwara, Nakazono, and Ueda 2015).

3. Forecast Accuracy of Inflation Expectations Function in Q-JEM

This section discusses some specifications of the inflation expectations function in Q-JEM, based on the literature survey in the previous section. Since the "price stability target" of 2 percent was introduced in 2013, Q-JEM has been operated through a process of trial and error with various specifications of the inflation expectations function. We will look at the model's forecast of inflation expectations and its forecast accuracy when these specifications are incorporated into Q-JEM.

3-1. Specifications and Data

(Consumer Prices Function)

First, we present the specification of consumer prices function (all items less fresh food and energy) in Q-JEM.[9] As in the models used by many other central banks, the inflation rate depends on inflation expectations as well as the output gap, based on the concept of the New Keynesian Phillips curve. To take into account inflation inertia, the own lags of the dependent variable are also included in the explanatory variables.[10] Specifically, the function is expressed as Equation (1) below.

$$\pi_t = \beta_0 (\pi_{t-1} + \pi_{t-2})/2 + (1 - \beta_0)\pi^e_{t,l} + \beta_1 y_t + \beta_2 x_t + \epsilon_t \quad (1)$$

π_t is the seasonally adjusted quarterly (annualized) rate of change in consumer prices (all items less fresh food and energy), $\pi^e_{t,l}$ is the medium- to long-term inflation expectations[11] (the definition is described below), y_t is the output gap, x_t represents the other explanatory variables including the real wage gap and non-energy material prices,[12] and ϵ_t is the error term.[13] The parameters β_0, β_1, and β_2 are estimated using the actual data (the estimation result is summarized in Reference Table; the same applies to the equations below).

(Inflation Expectations Function)

Next, we consider three specifications of the function of medium- to long-term inflation expectations. The first is a simple specification that considers only the mechanism of "sticky information" in addition to the inflation target as in Equation (2) below (hereafter referred to as "simple sticky information" specification).

$$\pi^e_{t,l} = \theta_1 \pi^e_{t-1,l} + (1 - \theta_1)\pi^*_t + \epsilon_t \quad (2)$$

The first term on the right-hand side is the own lag of medium- to long-term inflation expectations that captures the mechanism of sticky information. The second term, π^*_t, is

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9 The consumer energy prices function is specified separately in Q-JEM, which depends on the prices of crude oil, LNG, and others.

10 The inflation inertia has a direct impact on the inflation rate, separately from the channel through inflation expectations, including the mechanism of adaptive expectations that will be discussed later.

11 In theory, the inflation rate depends on short-term (e.g., one-period-ahead) inflation expectations, and then the short-term inflation expectations are often considered to depend on medium- to long-term inflation expectations, trend inflation, and other factors (as specified in earlier versions of Q-JEM). However, in the current version of Q-JEM, for simplicity, we assume that the inflation rate depends directly on medium- to long-term inflation expectations.

12 The real wage gap is the deviation from the trend determined by labor productivity and other factors. The non-energy material prices are represented by an index of various market data including agricultural and livestock products, nonferrous metals (S&P GSCI Non-Energy).

13 This specification of the consumer prices function is the same as in an earlier version of Q-JEM (Hirakata et al. 2019), except for the "other explanatory variables."

the inflation target,[14] which is a constant of annually 1 percent up to the fourth quarter of 2012 and 2 percent from the first quarter of 2013. The parameter θ_1 is estimated using the data from the fourth quarter of 1991, when the data on medium- to long-term inflation expectations became available.

The second specification takes into account the mechanism of "adaptive expectations" in addition to the sticky information, with reference to the FRB's model (FRB/US) and the ECB's model (ECB-BASE), as in Equation (3) below (hereafter referred to as "FRB/US and ECB-BASE type" specification).

$$\pi_{t,l}^e = \theta_2 \pi_{t-1,l}^e + (1 - \theta_2)\{\delta \pi_{t-1}^{ff} + (1 - \delta)\pi_t^*\} + \epsilon_t \qquad (3)$$

π_{t-1}^{ff} included in the second term on the right-hand side is the seasonally adjusted quarterly (annualized) rate of change in consumer prices (all items less fresh food),[15] which captures the mechanism of adaptive expectations, which is influenced by past actual values of inflation.[16] The parameters θ_2 and δ are estimated using the data.

Finally, the third specification also takes into account adaptive expectations, but in order to more accurately reflect the situation in Japan, it allows the possibility that the parameter δ, which is fixed in the FRB/US and ECB-BASE type specification of Equation (3) and determines the weight of adaptive (backward-looking) expectations and forward-looking expectations based on the inflation target, may change over time. While Q-JEM has been operated through a process of trial and error with several specifications taking into account this possibility, here we take as an example the "Trend Inflation Projection System (TIPS)" developed by Takahashi (2016) and introduced by Hirakata et al. (2019).[17] It captures adaptive expectations by extracting a permanent (long-term)

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[14] Although no explicit inflation target (price stability target) was set before 2013, the "understanding of medium- to long-term price stability" was set in 2006 to be in the range of 0-2 percent with the midpoint of 1 percent, and the "price stability goal in the medium to long term" of 1 percent was set in 2012.

[15] We use consumer prices (all items less fresh food) as a variable to capture adaptive expectations because the fit to the data and the forecast accuracy improve when energy prices are included in the variable. Note that the core consumer prices (excluding energy prices) are used in the FRB/US model and GDP deflator (year-on-year rate of change) is used in the ECB-BASE model, so there is no particular consensus among central banks on this point.

[16] Although only the previous period's inflation rate is represented in Equation (3) as the variable capturing adaptive expectations, longer past inflation rates also affect the current medium- to long-term inflation expectations through the own-lag term (the first term on the right-hand side) capturing sticky information.

[17] Another specification used in Q-JEM was the one introduced in Ikeda et al. (2022). While in the TIPS, δ is time-dependent in the sense that it is assumed to converge to zero (i.e., the degree of

component from consumer prices data, and formulates the possibility that the weight of adaptive expectations and forward-looking expectations based on the inflation target (parameter δ in Equation (3)) may vary, as follows (hereafter referred to as "TIPS" specification).

$$\pi_{t,l}^{e} = \theta_3 \pi_{t-1,l}^{e} + (1-\theta_3)\{\delta_t \tau_{t-1} + (1-\delta_t)\pi_t^*\} + \beta y_{t,l}^{e} + \epsilon_t \tag{4}$$

$$\delta_t = \omega \delta_{t-1} + \kappa D_t + \mu_t \tag{4'}$$

τ_{t-1} in the second term on the right-hand side of Equation (4) is a permanent component extracted from several core inflation measures using a time-series analysis (Beveridge-Nelson decomposition)[18], and $y_{t,l}^{e}$ in the third is medium- to long-term expectations of the output gap (which is considered to be close to zero). δ_t is a variable that takes values between 0 and 1 and converges (decreases) to zero over time under the assumption that $0 < \omega < 1$, as shown in Equation (4′). This implies that $(1-\delta_t)$, which represents the degree of credibility or anchoring to the inflation target, converges (increases) to one over time. However, since the degree of credibility might have changed temporarily and discontinuously in the first quarter of 2013, when the inflation target was raised from 1 percent to 2 percent, a dummy variable D_t which takes 1 only for that quarter, is added as an explanatory variable. ϵ_t and μ_t are error terms, and the parameters (θ_3, β, ω, κ) in Equations (4) and (4') are estimated systematically by Bayesian methods.

(Overview of the Data)

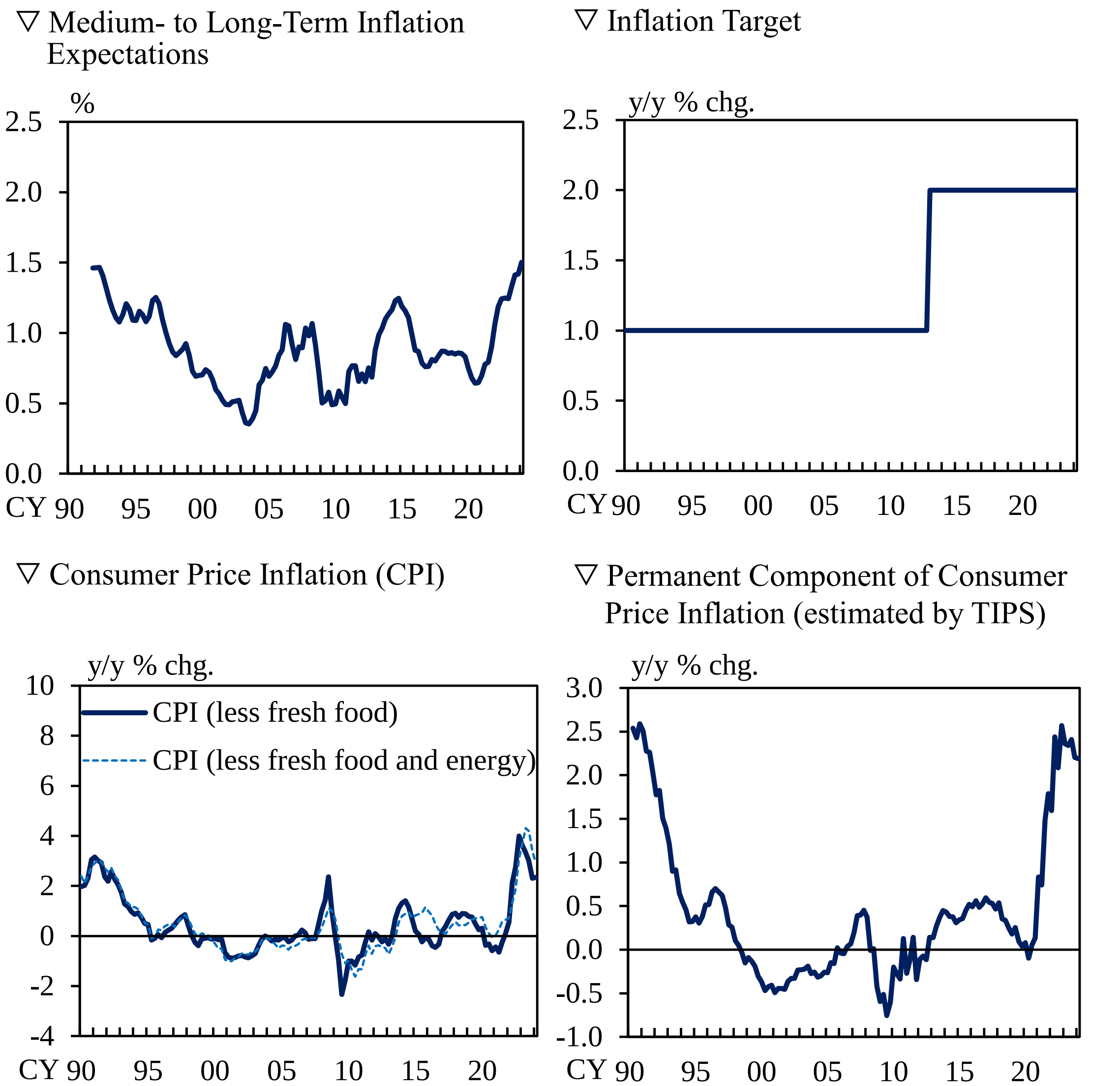
Figure 1 provides an overview of the data for the main variables used in the above three specifications of the inflation expectations function. First, for the medium- to long-term inflation expectations (Figure 1, top left) as the dependent variable, we use the "composite index" of 10-year-ahead inflation expectations constructed by Osada and Nakazawa (2024) and shown in Bank of Japan (2024). This is constructed by estimating economic agents' inflation expectations by forecast horizon using the Dynamic Nelson-Siegel model from various survey data on households, firms, and experts, and then aggregating economic agents' inflation expectations for each forecast horizon using principal component analysis, from which the composite index of 10-year-ahead inflation

credibility or anchoring to the inflation target increases) over time, in the specification of Ikeda et al. (2022), δ is state-dependent in the sense that the degree of anchoring depends on the divergence of inflation expectations from the inflation target (the closer they are, the better anchored).

[18] Specifically, following Takahashi (2016), we use four measures of core inflation: the Consumer Price Inflation (CPI) for all items less fresh food, the CPI for all items less fresh food and energy, the CPI for all items less food and energy, and the trimmed mean. We extract the common permanent component from these measures using the Beveridge-Nelson decomposition.

expectations is obtained. Next, the inflation target (Figure 1, top right) is set at 1 percent up to the fourth quarter of 2012 and 2 percent from the first quarter of 2013 onward, as mentioned earlier. The year-on-year rate of changes in consumer prices (all items less fresh food and those less fresh food and energy, Figure 1, bottom left) and the permanent component extracted from several core inflation measures using the Beveridge-Nelson decomposition (Figure 1, bottom right) are also shown.

(Figure 1) Overview of the Data



Note: The CPI figures are estimates by the Bank of Japan staff and exclude the effects of the consumption tax hikes, policies concerning the provision of free education, and travel subsidy programs. The CPI (less fresh food and energy) figures also exclude mobile phone charges. The same applies below.

Sources: Ministry of Internal Affairs and Communications; Bank of Japan; Bloomberg; QUICK, "QUICK Monthly Market Survey <Bonds>"; Consensus Economics Inc., "Consensus Forecasts."

3-2. Comparison of Forecast Accuracy

In the following, we analyze the forecast accuracy of medium- to long-term inflation expectations and consumer price inflation using the above three specifications (simple sticky information, FRB/US and ECB-BASE type, and TIPS) of inflation expectations function. Specifically, based on the inflation expectations function and consumer prices function estimated sequentially by fixing the sample starting point (the early 1990s for both functions) and extending the ending point quarter by quarter from the fourth quarter of 2012,[19] we calculate the out-of-sample forecasts of medium- to long-term inflation expectations and consumer price inflation up to two years (eight quarters) ahead from each quarter and aggregate the forecast errors over time. In doing so, to focus on comparing the forecast performances of the above specifications of inflation expectations function, variables other than medium- to long-term inflation expectations and consumer price inflation (all items less fresh food and energy), including the output gap, wages, and energy prices, are assumed to be foreseen perfectly (take actual values).

(Forecast Accuracy from 2013)

First, based on the inflation expectations function and consumer prices function estimated using the data up to the fourth quarter of 2012, just before the "price stability target" of 2 percent was set, we calculate the out-of-sample forecasts from the first quarter of 2013. Figure 2 shows that the simple sticky information and the FRB/US and ECB-BASE type specifications of inflation expectations function under-predicted both medium- to long-term inflation expectations and consumer price inflation. In contrast, the TIPS specification almost accurately predicted the rise in medium- to long-term inflation expectations, but still under-predicted consumer price inflation.

One possible explanation for the under-prediction of medium- to long-term inflation expectations is that the significant change in the monetary policy framework during this phase might have led to discontinuous changes in the mechanism by which people form their inflation expectations.[20] For example, if economic agents that had previously not

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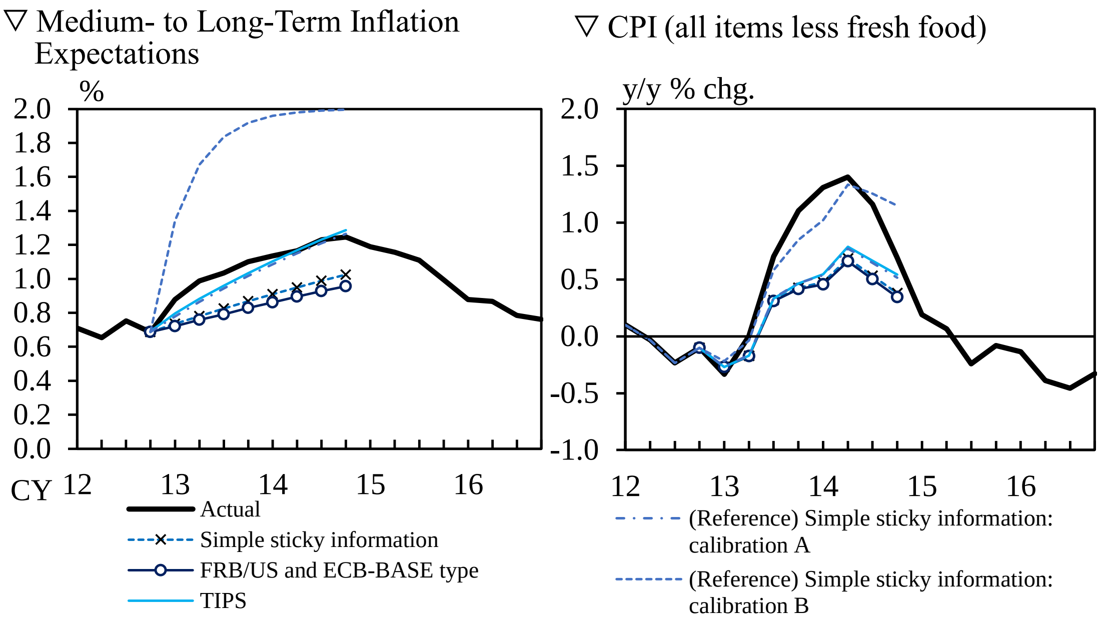
[19] The fit of the inflation expectations function to the data within the estimation period (in-sample forecast accuracy) is good under all these specifications and there are no significant differences between them. As shown in Reference Table, the adjusted R-squared in full-sample estimation of inflation expectations is 0.92 for both the simple sticky information and the FRB/US and ECB-BASE type specifications.

[20] According to the Bank of Japan's communication at that time, one of its basic thinking in introducing QQE was "to convey the Bank's strong policy stance to markets and economic entities with clarity and intelligibility, thereby dramatically changing the expectations of market participants as well as firms and households" (Kuroda 2013).

updated their information sets or taken no interest in the Bank of Japan's inflation target updated their information set or increased their interest discontinuously during this phase, it would be captured in the simple sticky information specification in Equation (2) not only as a change in the inflation target (an increase in π_t^*) but also as a discontinuous change in the parameter to become more responsive to the inflation target (decrease in θ_1). Figure 2 also shows, for reference, the out-of-sample forecasts of medium- to long-term inflation expectations and consumer price inflation from the first quarter of 2013, when the parameter θ_1 of the simple sticky information is calibrated to a smaller value than the value estimated using data up to the fourth quarter of 2012 (two sets of calibration: 0.93 for Calibration A, and 0.5 for Calibration B, compared with the estimated value of 0.96).[21] Calibration A almost accurately predicted the rise in medium- to long-term inflation expectations, but it still under-predicted consumer price inflation (these forecast paths mostly overlap with those from the TIPS specification). Conversely, Calibration B almost accurately predicted the rise in consumer price inflation, but significantly over-predicted medium- to long-term inflation expectations. The under-prediction of consumer price inflation even when medium- to long-term inflation expectations are accurately predicted is a phenomenon that will be seen in later phases (especially in the 2020s) as well, suggesting the existence of some factors not captured by the consumer prices function in Q-JEM (Equation (1)). The forecast accuracy of consumer price inflation is discussed in more detail in Appendix.

[21] In one of several versions of Q-JEM at that time, a specification with the sticky information mechanism similar to those shown in Figure 2 as reference (especially Calibrations B) was considered, in which the formation mechanism of medium- to long-term inflation expectations changed discontinuously under certain conditions regarding the development of consumer price inflation after the introduction of QQE.

(Figure 2) Forecast Accuracy from 2013

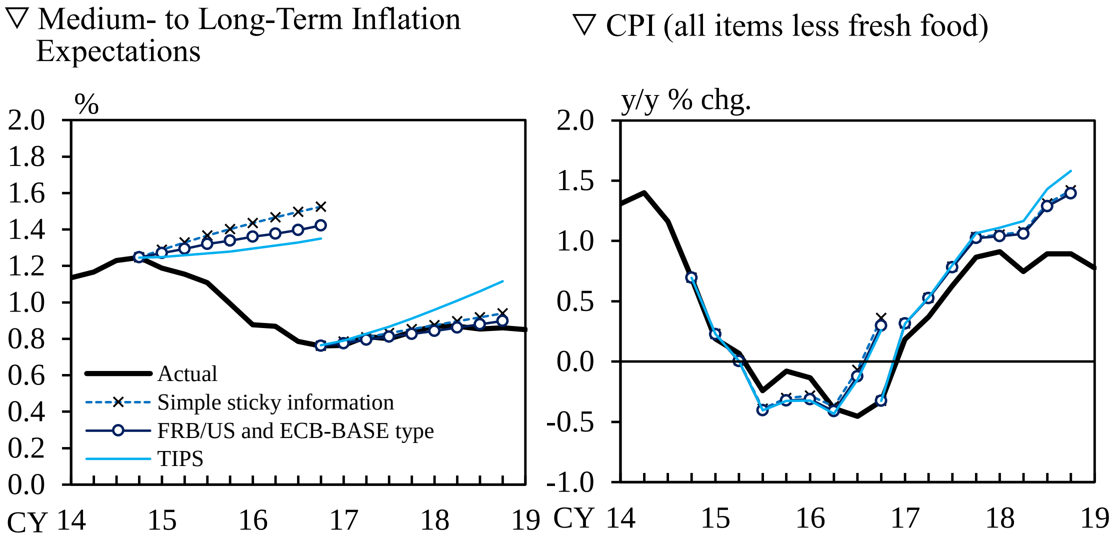


Sources: Ministry of Internal Affairs and Communications; Bank of Japan; Bloomberg;
QUICK, "QUICK Monthly Market Survey <Bonds>";
Consensus Economics Inc., "Consensus Forecasts."

(Forecast Accuracy around 2015-18)

Subsequently, consumer price inflation (all items less fresh food) declined rapidly in 2014 due to the drop in oil prices and other factors, and then medium- to long-term inflation expectations also started to decline clearly around 2015. Based on the inflation expectations function and consumer prices function estimated using the data up to the fourth quarter of 2014, we calculate the out-of-sample forecasts from the first quarter of 2015. Figure 3 shows that none of the three specifications of inflation expectations function predicted the decline in medium- to long-term inflation expectations from 2015. For the FRB/US and ECB-BASE type and the TIPS specifications that take into account adaptive expectations, however, the forecast errors were relatively small (the out-of-sample forecast paths were closer to the actual path) to the extent that they reflected the decline in the actual inflation including energy prices. During this phase, the forecast accuracy of consumer price inflation was generally good, although the forecast errors of longer-quarter-ahead inflation was widening, largely due to the assumption that the decline in energy prices was foreseen perfectly.

(Figure 3) Forecast Accuracy around 2015-18



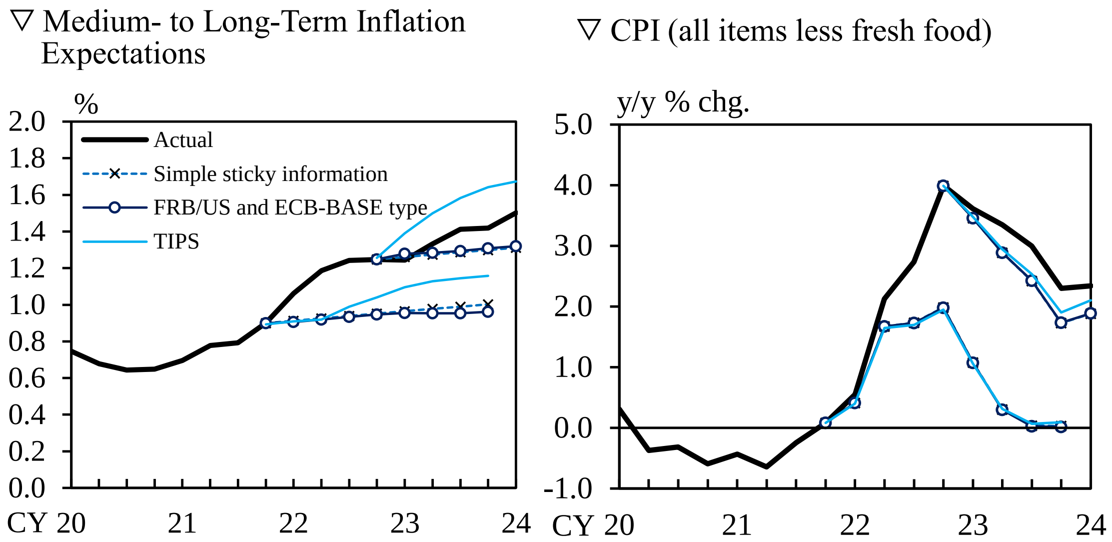
Sources: Ministry of Internal Affairs and Communications; Bank of Japan; Bloomberg;
QUICK, "QUICK Monthly Market Survey <Bonds>";
Consensus Economics Inc., "Consensus Forecasts."

From around 2017, medium- to long-term inflation expectations have ceased to decline and consumer price inflation has turned positive. In this phase, by extending the estimation period and calculating the out-of-sample forecasts, we can see that the simple sticky information and the FRB/US and ECB-BASE type specifications were able to predict medium- to long-term inflation expectations almost accurately. The TIPS specification, however, over-predicted inflation expectations partly because the credibility of the inflation target was increasing over time in this specification. Meanwhile, consumer price inflation in this phase was slightly over-predicted with all of the three specifications of inflation expectations function.

(Forecast Accuracy from 2022-23)

Since around 2022 after the pandemic, Japanese consumer price inflation has surged to around 4 percent temporarily, triggered by a sharp rise in import prices including energy prices, and medium- to long-term inflation expectations have also been gradually increasing toward 2 percent. Based on the inflation expectations function and consumer prices function estimated using the data up to the fourth quarter of 2021, we calculate the out-of-sample forecasts from the first quarter of 2022. Figure 4 shows that all of the three specifications of inflation expectations function under-predicted the rise in medium- to long-term inflation expectations, while the forecast errors for the TIPS specification were relatively small. Consumer price inflation was also under-predicted, especially the forecast errors of longer-quarter-ahead inflation was widening, even under the assumption that the surge in energy prices were foreseen perfectly.

(Figure 4) Forecast Accuracy from 2022-23



Sources: Ministry of Internal Affairs and Communications; Bank of Japan; Bloomberg; QUICK, "QUICK Monthly Market Survey <Bonds>"; Consensus Economics Inc., "Consensus Forecasts."

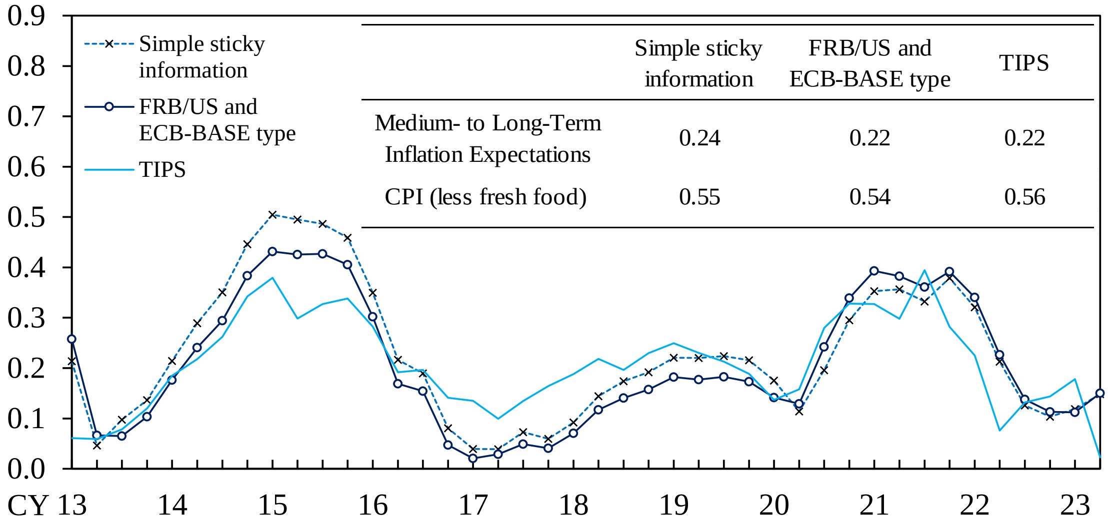
Since 2023, while the year-on-year rate of change in consumer prices (all items less fresh food) has turned downward due to the effects of Japanese government's economic measures to reduce energy prices, medium- to long-term inflation expectations have continued to rise steadily toward 2 percent. In this phase, by extending the estimation period and calculating the out-of-sample forecasts, we can see that the simple sticky information and the FRB/US and ECB-BASE type specifications still under-predicted inflation expectations although the forecast errors became smaller compared to the out-of-sample forecasts in the previous year. The TIPS specification, on the contrary, over-predicted inflation expectations in this phase. The declining consumer price inflation was still under-predicted with all of the three specifications of inflation expectations function, although the forecast errors became smaller as those of inflation expectations. The forecast accuracy of consumer price inflation in this phase is also discussed in Appendix.

(Forecast Errors over the All Phases since 2013)

We have discussed so far the forecast accuracy of medium- to long-term inflation expectations and consumer price inflation by time period, but finally we will evaluate the forecast accuracy for all phases from the first quarter of 2013 to the most recent quarter (the first quarter of 2024). First, from the three specifications of inflation expectations function, we calculate the root mean squared errors (RMSEs) at each forecasting point for the out-of-sample forecasts of inflation expectations up to 8 quarters ahead. Figure 5 shows these quarterly RMSEs, from which we can see that the RMSEs have changed significantly over time and that the relative forecast accuracy between the three specifications has varied from phase to phase, that is, no single specification has always provided the best forecast accuracy over the all phases. Then, averaging the quarterly RMSEs over the all forecast starting points, we obtain the result that the FRB/US and ECB-BASE type and the TIPS specifications that take into account adaptive expectations provide slightly smaller RMSEs (better forecast accuracy) than the simple sticky information specification on average. These two specifications, as mentioned earlier, reflected the decline in the actual inflation including oil prices through the mechanism of adaptive expectations especially when inflation expectations turned downward in 2015, which contributed to the relatively high forecast accuracy compared to the simple sticky information specification even on average over the all phases. While the average RMSEs from these two specifications are almost the same (0.22) for the 8-quarter-ahead out-of-sample forecasts, the TIPS specification provides a smaller average RMSE for the 4-quarter-ahead forecasts and the FRB/US and ECB-BASE type specification provides a smaller one for the 12-quarter-ahead forecasts.[22]

[22] Regarding the forecast accuracy of consumer price inflation, the FRB/US and ECB-BASE type specification provides the smallest average RMSE (best forecast accuracy) among the three specifications of inflation expectations function.

(Figure 5) RMSEs of Inflation Expectations



	Simple sticky information	FRB/US and ECB-BASE type	TIPS
Medium- to Long-Term Inflation Expectations	0.24	0.22	0.22
CPI (less fresh food)	0.55	0.54	0.56

Notes: 1. The quarterly RMSEs are based on out-of-sample forecasts calculated by fixing the sample starting point at the fourth quarter of 1991 and extending the ending point quarter by quarter from the fourth quarter of 2012 in estimating the functions. The horizontal axis shows the forecast starting point.

2. For the forecast starting points prior to the second quarter of 2022, the RMSEs are calculated based on the 8-quarter-ahead forecasts. For the forecast starting points from the third quarter of 2022 to the second quarter of 2023, the RMSEs are calculated sequentially based on the 7- to 4-quarter-ahead forecasts since the ending point of the actual data is the first quarter of 2024.

3. The table shows the average RMSEs for the 8-quarter-ahead forecasts over the all forecast starting points.

The above results suggest that the mechanism of adaptive expectations has played a certain role in the formation of inflation expectations in Japan. At the same time, the results can also be interpreted that there was no significant difference in the forecast accuracy between the three specifications, suggesting that the formation mechanism of inflation expectations during the period covered by this analysis was highly uncertain. It might not be easy to accurately capture the mechanism by some specifications of inflation expectations function with parameters fixed (even though estimated sequentially) over the estimation period. In particular, the result that even the TIPS specification, which is complex enough to allows the possibility that the weight of adaptive expectations may change over time, provides little improvement in forecast accuracy compared to the FRB/US and ECB-BASE type specification, which has been used in the U.S. and the euro area where medium- to long-term inflation expectations are stable, suggests the difficulty in accurately capturing the formation mechanism of inflation expectations in Japan. Having said that, Figure 5 also shows that the quarterly RMSEs in recent years have been shrinking (forecast accuracy has been improving) with all the three specifications of inflation expectations function, as medium- to long-term inflation expectations have steadily risen toward 2 percent.[23]

4. Simulations of Inflation Expectations Using Q-JEM

In this section, we conduct simulations of the responses of medium- to long-term inflation expectations and consumer price inflation to exogenous shocks, such as fluctuations in oil prices, using Q-JEM. We employ the FRB/US and ECB-BASE type specification of inflation expectations function, which is relatively simple and easy to handle, and provided relatively high forecast accuracy as shown in the previous section. Under the FRB/US and ECB-BASE type specification that takes into account adaptive expectations, various shocks affect medium- to long-term inflation expectations through the actual value of consumer price inflation (all items less fresh food), which is included in the inflation expectations function as an explanatory variable.[24] This section examines the uncertainty of inflation expectations under the mechanism of adaptive expectations, leaving aside the uncertainty of the expectations formation mechanism itself, which was discussed in the previous section. While the previous section analyzed the forecast accuracy by assuming that variables other than medium- to long-term inflation expectations and consumer price inflation are foreseen perfectly, this section assumes that many variables, including real GDP components such as private consumption and capital investment, vary endogenously following the functions of Q-JEM (for details, see Haba et al. 2025; Hirakata et al. 2019). The policy interest rate (call rate) also varies endogenously following a standard Taylor rule, but does not take negative values under the assumption of the zero lower bound.[25] For simplicity, we do not consider unconventional monetary policies including negative interest rates.[26] In addition, we assume that energy prices, exchange rates, foreign variables, and fiscal variables are exogenous, and their values are set with reference to actual data and market forecasts.

In the following, we first show the responses of medium- to long-term inflation

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[23] The relatively small quarterly RMSE from the third quarter of 2022 shown in Figure 5 is partly due to the shorter forecast horizon. However, the quarterly RMSE for 4-quarter-ahead (rather than 8-quarter-ahead) forecasts are also on a declining trend from 2022 onward.

[24] Under the simple sticky information type specification, shocks to consumer price inflation do not directly affect medium- to long-term inflation expectations.

[25] The Taylor rule equation is $i_t = \max\{\rho i_{t-1} + (1-\rho)[i_t^* + 0.5y_t + 1.5(\pi_t^{ff} - \pi_t^*)],\ 0\}$, where i_t is nominal policy rate, i_t^* is nominal equilibrium policy rate (determined by medium- to long-term inflation expectations, potential growth rate, etc.), and $\rho = 0.84$ (estimated based on actual data).

[26] See Haba et al. (2025) for an assessment of the effects of unconventional monetary policies using Q-JEM.

expectations and consumer price inflation to exogenous shocks with reference to the rates of decline in energy prices and other variables around 2014-16, and then simulate the impacts of shocks of the same magnitude occurring at a different time or in the opposite direction. Then, based on the historical distribution of all types of shocks computed from Q-JEM functions, including the inflation expectations function, we will use simulations (fan charts) to evaluate the future uncertainty of medium- to long-term inflation expectations.

4-1. Impact of Commodity Prices and Exchange Rates Fluctuations

(Setting of Shocks)

First, as assumptions of simulations, we set scenarios for exogenous shocks. As exogenous variables that affect medium- to long-term inflation expectations under adaptive expectations, we consider crude oil prices, LNG prices, and commodity prices excluding energy. In addition, since these prices are measured in a foreign currency, we also consider the effect of exchange rate fluctuations. In the simulations below, we assume that the four variables (crude oil prices, LNG prices, commodity prices excluding energy, and the U.S. dollar-yen exchange rate[27]) fall at a constant rate over four quarters (the yen appreciates against the dollar) and then move parallel to the baseline (in the absence of shocks), which implies the impact of the shocks on the level of each variable is permanent. The magnitude of the shocks to each variable is set so that the cumulative rate of decline over the four quarters (the range of change for the case of the U.S. dollar-yen rate) is the same as the cumulative rate of change from peak to bottom actually observed around 2014-16 (four to seven quarters, depending on the variable).[28]

(Parameter Sets of the Inflation Expectation Function)

Next, for the parameters of the FRB/US and ECB-BASE type specification of inflation expectations function (Equation (3) in Section 3), we consider several cases (parameter sets) in order to take into account various uncertainties while checking the model dynamics. In the first case, Case A, we set parameter values estimated using the full sample data (from the fourth quarter of 1991 to the first quarter of 2024). In the other two cases, Cases B and C, we set the values used in the FRB's model (FRB/US) and the ECB's

[27] In Q-JEM, the nominal and real effective exchange rates are formulated to fluctuate in response to the U.S. dollar-yen rate.

[28] The cumulative rates of change from peak to bottom are approximately 71.1 percent for oil prices, 27.8 percent for commodity prices excluding energy, 62.8 percent for LNG prices (on customs clearance basis) and 16.2 percent for the U.S. dollar-yen rate.

model (ECB-BASE). The specific parameter values for each case are shown in the table below. The value of the parameter for the actual consumer price inflation ($(1-\theta_2)\delta$), which represents the strength of adaptive expectations, is set to the smallest value in Case A (estimation) and to the largest value in Case C (ECB-BASE). The value of the parameter for the inflation target ($(1-\theta_2)(1-\delta)$), which represents the degree of anchoring, is also set lowest in Case A and highest in Case C. Note that neither FRB/US nor ECB-BASE estimates these values from the actual the U.S. nor the euro area data, so the differences between the three cases cannot be interpreted as differences in the actual inflation expectations formation mechanisms between Japan, the U.S., and the euro area.[29]

▽The Parameter Values in the Cases A-C

	Case A	**Case B**	**Case C**
$\boldsymbol{\theta_2}$	0.96***	0.90	0.75
$\boldsymbol{(1-\theta_2)\delta}$	0.01**	0.05	0.10
$\boldsymbol{(1-\theta_2)(1-\delta)}$	0.03**	0.05	0.15

Notes: 1. In Case A, the estimation period is from the fourth quarter of 1991 to the first quarter of 2024.
2. *** and ** denote statistical significance at the 1 and 5 percent level, respectively.

(Results of Simulations on Falling Commodity Prices and Yen Appreciation)

Under the above settings, Figure 6 (top left) shows the responses of medium- to long-term inflation expectations, in terms of the deviation from the no-shock baseline, to the above shocks in a low inflation period around 2014, when consumer price inflation (all items less fresh food and energy) was only about 1 percent. In all cases from A through C, inflation expectations decline for around six quarters from the time of the shocks, and then gradually return toward the baseline as the shocks decay to zero on a year-on-year basis. The peak of decline in Case B (after seven quarters) is about minus 0.4 percentage points, which is roughly close to the actual decline in medium- to long-term inflation expectations around 2014-16. The peak of decline in Case C is well above this, but then

[29] The Bank of Japan (2016, 2021) estimated a simple inflation expectations function explained by consumer price inflation in the previous quarter and the inflation target (no sticky information is considered) using actual data in Japan, the U.S., the U.K., and the euro area, and found that the estimated parameter value on consumer price inflation (representing the strength of adaptive expectations) in Japan is larger than that in the U.S., the U.K., and the euro area.

inflation expectations return to the baseline at a faster pace, partly due to the higher degree of anchoring.

Next, Figure 6 (top right) shows the responses of consumer price inflation (all items less fresh food and energy) to the same shocks. In all cases, the inflation rate declines somewhat sharply for six to eight quarters after the shocks due to spillovers (pass-through) from the decline in energy prices and the direct impact of the decline in commodity prices excluding energy. The decline in consumer price inflation is substantial even in Case A, where the decline in inflation expectations is limited. Still, the order of magnitude of the declines across the cases is the same as that in inflation expectations (the decline in Case A is the smallest and that in Case C is the largest).

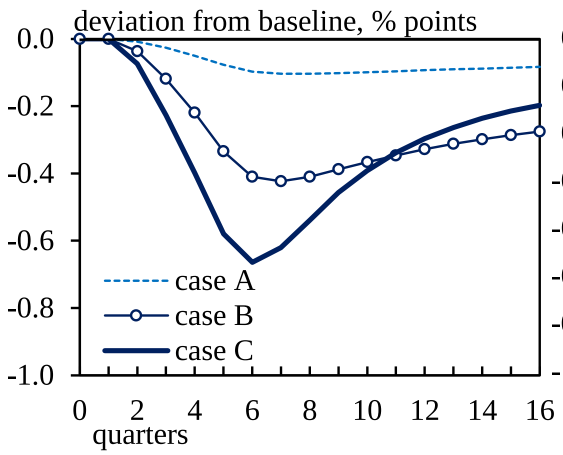
If these shocks (falling commodity prices and yen appreciation) of the same magnitude were to occur during the high inflation period in the 2020s, when consumer price inflation was about 3 percent in the baseline, the peak responses of medium- to long-term inflation expectations (Figure 6, bottom left) and consumer price inflation (Figure 6, bottom right) would have been slightly smaller compared to the responses during the low inflation period around 2014. In addition, the pace of return to the baseline would have been faster during the high inflation period in the 2020s. These differences arise because the economic environment assumed in the baseline differs between the high and low inflation periods. For example, in the low inflation period, the policy rate was subject to the zero lower bound, while in the high inflation period, the baseline policy rate was assumed to be positive and there was room for rate cuts. This partly explains the faster return to the baseline in the high inflation period, with the monetary easing taking effect over time.[30]

[30] In Case A, consumer price inflation rises above the baseline after the 12th quarter from the time of the shocks, which is a temporary overshoot mainly due to an improvement in the output gap as a result of monetary easing.

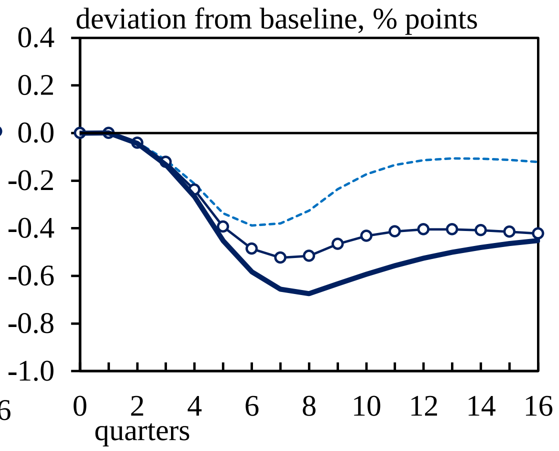
(Figure 6) Responses to Falling Commodity Prices and Yen Appreciation Shocks

▼ Low Inflation Period around 2014

▽ Medium- to Long-Term Inflation Expectations

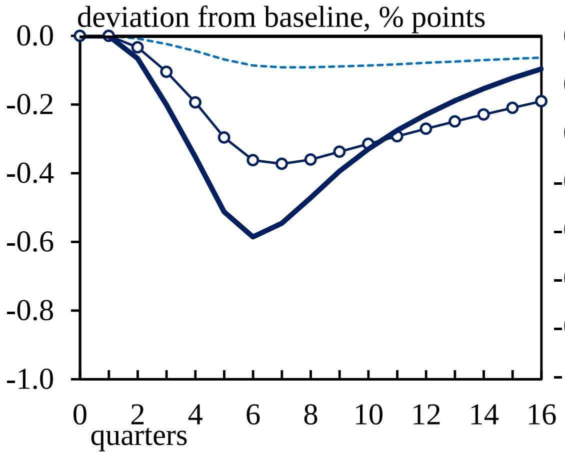


▽ CPI (all items less fresh food and energy)

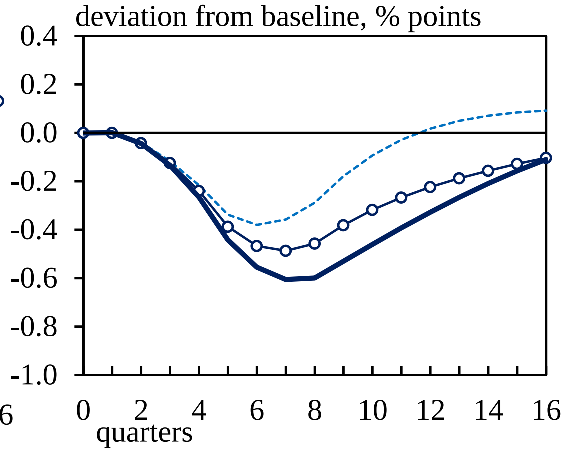


▼ High Inflation Period in the 2020s

▽ Medium- to Long-Term Inflation Expectations



▽ CPI (all items less fresh food and energy)



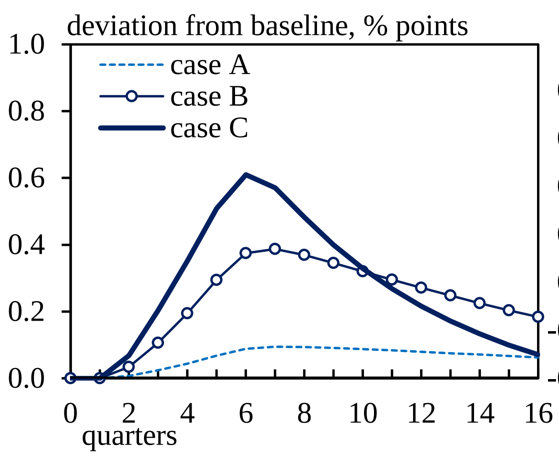
(Results of Simulations on Rising Commodity Prices and Yen depreciation)

In the following, we will also check the responses of medium- to long-term inflation expectations and consumer price inflation to shocks of the same magnitude as above in the opposite direction, i.e., rising commodity prices and yen depreciation. First, the positive peak responses of medium- to long-term inflation expectations (Figure 7, top left) and consumer price inflation (Figure 7, top right) to these shocks during the low inflation period around 2014 are roughly symmetric with the negative peak responses to falling commodity prices and yen appreciation, although the pace of return to the baseline is faster in response to rising commodity prices and yen depreciation. The difference in the pace of return is partly because there was no room to cut interest rates in response to falling commodity prices and yen appreciation, while it was possible to respond to shocks in the opposite direction by raising interest rates.

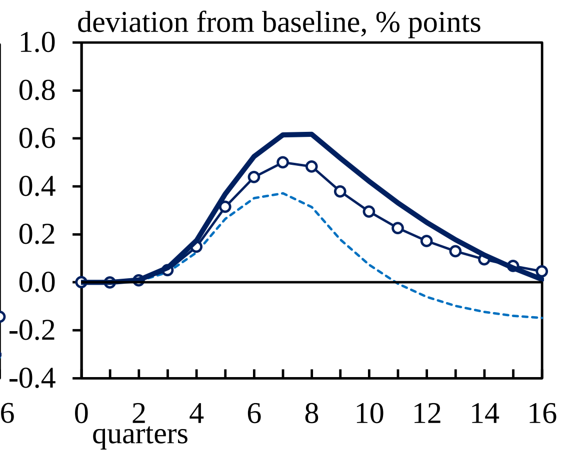
(Figure 7) Responses to Rising Commodity Prices and Yen Depreciation Shocks

▼ Low Inflation Period around 2014

▽ Medium- to Long-Term Inflation Expectations

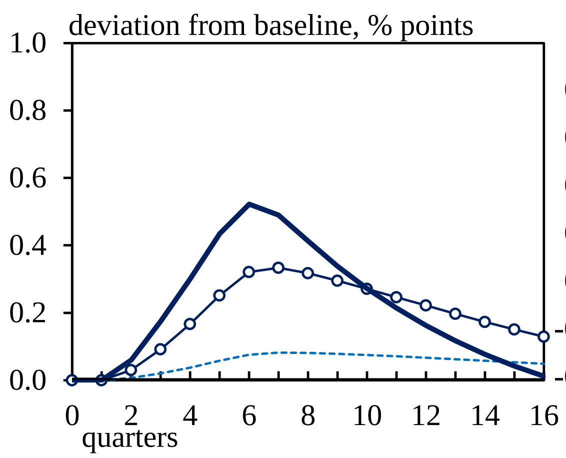


▽ CPI (all items less fresh food and energy)

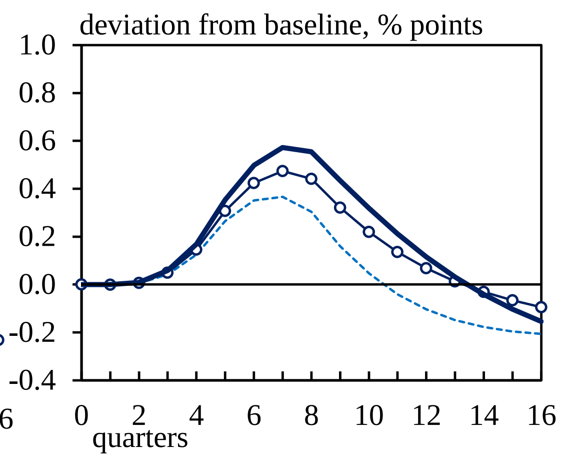


▼ High Inflation Period in the 2020s

▽ Medium- to Long-Term Inflation Expectations



▽ CPI (all items less fresh food and energy)



Finally, we check the responses of medium- to long-term inflation expectations (bottom left of Figure 7) and consumer price inflation (bottom right of Figure 7) to shocks of the same magnitude of rising commodity prices and yen depreciation during the high inflation period in the 2020s. The responses are roughly symmetric with those to falling commodity prices and yen appreciation in the same period, although the pace of return to the baseline tends to be slightly faster in response to rising commodity prices and yen deprecation than to shocks in the opposite direction.

4-2. Fan Charts of Medium- to Long-Term Inflation Expectations

The above simulations in the previous subsection show that the responses of medium- to long-term inflation expectations and consumer price inflation to shocks of the same type and magnitude can vary depending on the timing and direction of the shocks, due to the differences in economic environment and monetary policy responses.

In this subsection, we attempt to evaluate the uncertainty of inflation expectations for all types of shocks on the assumption of the mechanism of adaptive expectations. Specifically, we employ the FRB/US and ECB-BASE type specification of inflation expectations function with the parameter set of Case B, under which the range of decline in medium- to long-term inflation expectations in response to shocks to falling commodity prices and yen appreciation since around 2014 is roughly consistent with the actual data. We also employ the functions of other variables from Q-JEM and use their past forecast errors to calculate historical shock distributions for each of these variables including inflation expectations. Then we run simulations many times (5,000 times) giving shocks to all endogenous variables with estimated parameters based on their forecast errors distributions. Two starting points of the simulations are selected: one from the low inflation period and the other from the high inflation period, between which the levels of medium- to long-term inflation expectations are roughly the same but the actual consumer price inflation rates differ.[31] Figure 8 shows the simulated distributions (fan charts[32]) of medium- to long-term inflation expectations from both starting points. The fan chart for the high inflation period is above that for the low inflation period because the actual consumer price inflation affects the future inflation expectations through the mechanism of adaptive expectations. In other words, even if the levels of inflation

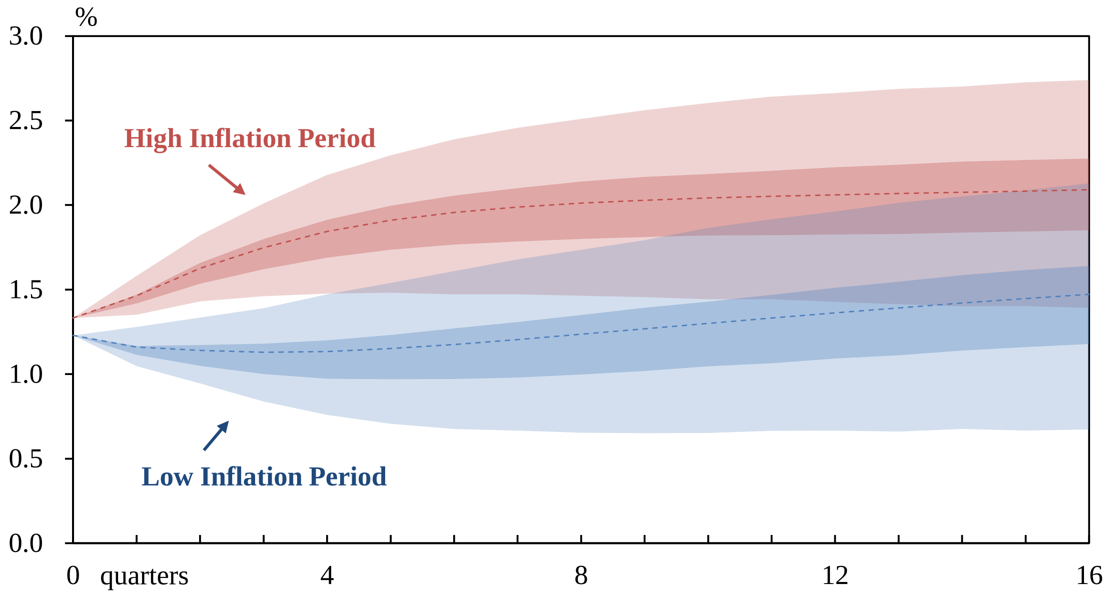
[31] For variables other than those related to prices, we conduct simulations under basically the same conditions at the two starting points.

[32] For instance, Ishikawa et al. (2012) explain the details of creating fan charts and examples of their use.

expectations at the start of the simulation are roughly the same between the two periods, subsequent inflation expectations are more likely to rise in the period when the recent actual consumer price inflation is higher.

A closer look at the shape of the fan charts shows that they are slightly downward skewed. This is due not only to the downward bias in the past forecast errors of Q-JEM functions, but also to the higher likelihood that the zero lower bound on the nominal interest rate will impede monetary policy response (monetary easing) in the event of downward shocks to inflation expectations, as shown in the simulations on commodity prices and exchange rates in the previous subsection.[33] The above results suggest that while medium- to long-term inflation expectations are likely to rise toward 2 percent given the recent increase in the actual consumer price inflation, it should also be noted that their downside risks are still relatively large.

(Figure 8) Fan Charts of Medium- to Long-Term Inflation Expectations



Note: The light shaded areas indicate the 90 percentile bands, whereas the dark shaded areas indicate the 40 percentile bands. The dotted lines show the simulated medium- to long-term inflation expectations in the absence of shocks.

[33] In general, it has been pointed out that economic activity and inflation may be more significantly depressed by the uncertainty of various exogenous shocks at the zero lower bound than otherwise (Nakata 2017, among others).

5. Conclusion

We have examined the formation mechanism of medium- to long-term inflation expectations in Japan using the Bank of Japan's large-scale macroeconomic model Q-JEM, from the perspective of the model's past forecast accuracy and its assessment of future uncertainty. Once again, the main conclusions from the analysis in this paper are as follows. First, from the comparison of the forecast accuracy of various specifications of the inflation expectations function in the model, we find that specifications that take into account the mechanism of adaptive expectations, which is influenced by past actual values of inflation, provided relatively high forecast accuracy on average since 2013. However, the relative forecast accuracy between different specifications varied from phase to phase, suggesting a large uncertainty in the expectations formation mechanism itself. Second, from the assessment of future uncertainty of inflation expectations based on the past forecast errors of Q-JEM, we find that inflation expectations are more likely to rise when the recent actual inflation is higher, under the assumption of adaptive expectations mechanism.

Despite the trial and error processes in the specification of inflation expectations function in Q-JEM mentioned in the introduction, and no matter how complex the specification of inflation expectations function we adopt, it has been difficult to accurately capture the formation mechanism of inflation expectations throughout the various phases since 2013, as suggested by our analysis of forecast accuracy. However, with medium- to long-term inflation expectations steadily rising toward 2 percent, as has been in recent years, it is possible that the formation mechanism of inflation expectations itself is becoming less uncertain. If that is the case, a relatively simple specification such as the FRB/US and ECB-BASE type may allow the model to operate stably in the future. On the other hand, our simulation analysis reveals that inflation expectations can fluctuate in complex ways in response to various shocks under the assumption of adaptive expectations mechanism. In any case, we still need to further deepen our understanding of the formation mechanism of inflation expectations, with reference to academic research and model operations at other central banks.

Appendix: Forecast Accuracy of Consumer Prices Functions in Q-JEM
--- Phases around 2013-16 and from 2022-23 ---

In Section 3-2 of the main text, we have analyzed the forecast accuracy of medium- to long-term inflation expectations and consumer price inflation using Q-JEM, mainly comparing several specifications of the inflation expectations function, through various phases since 2013. Of these, especially in the phases of price hikes immediately after the introduction of QQE in 2013 and from 2022, consumer price inflation tended to be under-predicted even when medium- to long-term inflation expectations were somewhat accurately predicted (or rather over-predicted) under the assumption that the yen depreciation and the rise in energy prices were foreseen perfectly.

In this appendix, we attempt to provide some interpretation of the background of forecast errors of consumer price inflation in the above phases of price hikes, based on the consumer prices functions in Q-JEM including the Phillips curve of Equation (1) in the main text.[34] In Appendix Figure below, the actual year-on-year rate of change in consumer prices (all items less fresh food) is decomposed into the contributions of main explanatory variables in Q-JEM, namely, medium- to long-term inflation expectations, the output gap, the exchange rate, and crude oil prices. The figure also shows the out-of-sample forecasts of consumer price inflation from the first quarter of 2013, 15, 22, and 23, as in Figures 2 through 4 in the main text.[35] Since these forecasts are calculated under the assumption that variables other than inflation expectations are foreseen perfectly, the contributions of "Output gap" and "Exchange rate and crude oil prices" in the figure do not affect the forecast errors of consumer price inflation (the difference between the actual CPI and the forecasts in the figure). These forecast errors are attributed to the forecast errors of medium- to long-term inflation expectations (shown in Figures 2 through 4) and "Other inflation-specific factors," i.e., factors that cannot be explained by the main explanatory variables of the consumer prices functions in Q-JEM.[36]

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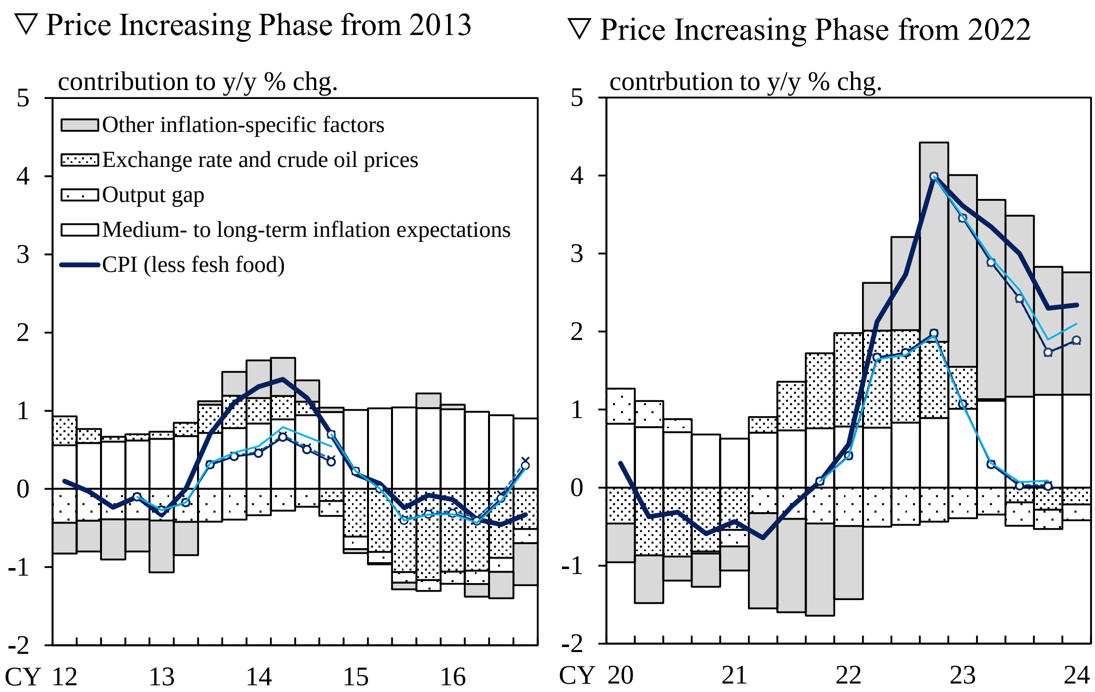
[34] As mentioned in Section 3-1 of the main text, the consumer prices functions in Q-JEM are composed of several functions: in addition to the function for all items less fresh food and energy (the Phillips curve), there are separate functions for energy prices and other items. The fit of the estimated Phillips curve to the data is poorer (the adjusted R-squared is 0.69, see Reference Table) than that of the inflation expectations function (the adjusted R-squared is 0.92 under the simple sticky information and the FRB/US and ECB-BASE type specifications).

[35] While Q-JEM functions in calculating the out-of-sample forecasts are estimated sequentially using the data up to the forecast starting points (as explained in Section 3-2 in the main text), the functions in decomposing the contributions of explanatory variables are estimated using the full-sample data.

[36] "Other inflation-specific factors" include not only the estimation errors of the consumer prices

(Appendix Figure) Decomposition of CPI (all items less fresh food) by Q-JEM



Note: The three lines from the fourth quarter of 2012, 14, 21, and 22 show the out-of-sample forecasts of consumer price inflation under the three specifications of inflation expectations function (the same as in Figures 2 through 4 in the main text).
Source: Ministry of Internal Affairs and Communications.

In the phase immediately after the introduction of QQE in 2013, while medium- to long-term inflation expectations rose only moderately, the inflation-specific factors that cannot be explained by the Phillips curve in Q-JEM pushed up consumer price inflation. (In the meantime, the contribution of yen depreciation was largely offset by the contribution of the output gap that had remained negative since before the introduction of QQE.) As a result, even though the TIPS specification of inflation expectations function almost accurately predicted the rise in medium- to long-term inflation expectations (Figure 2 in the main text), it under-predicted consumer price inflation. In other words, even though medium- to long-term inflation expectations did not rise rapidly toward 2 percent, consumer price inflation rose steadily toward 2 percent for about a year after the introduction of QQE. Subsequently, the decline in consumer price inflation from 2014 was explained by the dissipation of the inflation-specific factors mentioned above and the

functions but also the contributions of explanatory variables (including the real wage gap) other than the main explanatory variables shown in Appendix Figure.

following sharp decline in "Exchange rate and crude oil prices (mainly the latter)."[37] Although none of the three specifications of inflation expectations function in Q-JEM were able to predict the decline in medium- to long-term inflation expectations from 2015 (Figure 3 in the main text), it had little impact on the forecast accuracy of consumer price inflation (except during the recovery phase of oil prices from 2016) under the assumption that the decline in oil prices were foreseen perfectly. Then, in the phase of price hikes from 2022, according to the decomposition by Q-JEM, the inflation-specific factors that cannot be explained by the yen depreciation and the surge in oil prices contributed significantly to the acceleration of consumer price inflation.[38] Even if the inflation expectations function in Q-JEM could predict a moderate increase in medium- to long-term inflation expectations to some extent (many specifications under-predicted it, while TIPS over-predicted it from 2023; Figure 4 in the main text), consumer price inflation would be under-predicted due to the above inflation-specific factors.

Regarding the background to the rapid acceleration of consumer price inflation in the 2020s, theoretical and empirical studies are underway in many countries, and various factors have been pointed out including the non-linearity of the Phillips curve.[39] Empirical studies in Japan suggest the possibility of structural changes in inflation dynamics,[40] including the strengthened linkage between wages and prices, and the possibility that firms' practices of keeping prices unchanged and people's zero-inflation norms, which had taken root under the long-lasting deflation and low inflation, are set to dissolve.[41] Also in the phase of price hikes in 2013, it was possible that some factors that caused non-linearity in inflation dynamics were at work, albeit on a small and temporary basis, in a similar manner to the phase in the 2020s, although a simple comparison cannot

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[37] Kawamoto and Nakahama (2017) examine the factors of fluctuations in consumer price inflation using historical decomposition of VAR analysis, focusing on the phase from 2013 to 2015.

[38] The inflation-specific factors contributed significantly in the negative direction to consumer price inflation during 2021, mainly due to the effects of the reduction in mobile phone charges.

[39] For instance, Benigno and Eggertsson (2023) show the possibility, both theoretically and empirically in the context of the U.S., that the slope of the Phillips curve may steepen in a non-linear manner when the labor market tightness increases beyond a certain level.

[40] Nakamura et al. (2024) apply the model of Bernanke and Blanchard (2024) to Japanese product and labor markets and find, among others, that some factors that could not be fully explained by the model (i.e., residuals) had continuously pushed up consumer price inflation since 2022 and those residuals were partly explained by positive wage growth shocks.

[41] Furukawa et al. (2024), using a dynamic state-dependent pricing model and microdata of consumer prices, show that the emergence of Japanese firms' practices of keeping prices unchanged since the 1990s (the zero-inflation norm) was explained not only by the fall in inflation but also by the rise in menu costs and the curvature of the demand curve, and that the latter factors have weakened as of 2023 to the levels in the early 1990s and contributed to the disappearance of the practices (norm).

be made because the triggers for price hikes and labor market conditions were different between the two phases. In any case, these phases were similar in that the acceleration of consumer price inflation occurred even though inflation expectations rose only moderately.

While we mainly discuss the uncertainty of inflation expectations in this paper, it should be noted that, even if the forecast accuracy of inflation expectations could be improved and their formation mechanism could be revealed, there would still be much unknown about inflation dynamics themselves.

(Reference Table) Estimation Results

▽CPI (all items less fresh food and energy; Equation (1))

Dependent variable : π_t	
β_0	0.74***
β_1	0.09**
β_2 : Material prices (q/q chg.)	0.005**
β_2 : Real wage gap	0.012*
β_2 : Dummy (before 2013)	-0.22*
Adjusted R^2	0.69

Notes: 1. The estimation period is from the second quarter of 1994 to the second quarter of 2023.
2. ***, **, and * denote statistical significance at the 1, 5 and 10 percent level, respectively.

▽Medium- to Long-Term Inflation Expectations

Dependent variable : $\pi^e_{t,l}$			
	Equation (2)	Equation (3)	Equation (4) and (4)'
θ_i	0.98***	0.96***	0.91
δ	—	0.30***	See footnote
β	—	—	0.30
ω	—	—	0.99
κ	—	—	0.33
Adjusted R^2	0.92	0.92	—

Notes: 1. The estimation period is from the fourth quarter of 1991 to the first quarter of 2024.
2. *** denotes statistical significance at the 1 percent level. The estimation results of Equation (4) and (4)' are the mean value of the posterior distribution obtained by Bayesian estimation.
3. The value of δ in the first quarter of 2024 is 0.55.

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