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Abstract

This paper investigates whether a series of unconventional monetary policies conducted by the Bank of Japan in 2013 contributed to an increase in long-run inflation expectations, which had been below 0 percent. Using a panel dataset of professional forecasts, we estimate the dynamic Nelson-Siegel model and extract long-run inflation expectations as a common factor. We find that the introduction of Quantitative and Qualitative Monetary Easing (QQE) in April 2013, rather than raising the inflation target from 1 percent to 2 percent in January 2013, significantly increased long-run inflation expectations in Japan. In addition to this outcome, we find that the correlation between short-run and long-run expectations has been reduced since the introduction of QQE. Overall, our results suggest that inflation expectations have been "re-anchored" to the level around 1 percent since the introduction of QQE, while the level is still short of the 2 percent target.

JEL Codes: C53, D84, E31, E37, E52.

Keywords: Anchoring of inflation expectations; Inflation expectations curve; State space model; Term structure of inflation expectations; Unconventional monetary policy.

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1 Introduction

There is a broad consensus today that the effective management of long-run inflation expectations is essential for successful monetary policy. However, since the outbreak of the global financial crisis in 2008, several studies have reported that inflation expectations in major countries remain at the historical low levels but are also sensitive to incoming news or temporary shocks (Galati et al. (2011), Nautz and Strohsal (2015), Buono and Formai (2018), and Corsello et al. (2019)). Such "de-anchoring" of inflation expectations brings a serious concern for central banks, especially when conventional policy tools are constrained by the effective lower bound. Since low inflation expectations imply high real interest rates, such unintended monetary tightening makes it difficult to "re-anchor" inflation expectations to the target level. Given that equilibrium real interest rates are expected to stay at low levels and the probability of the policy rate hitting the lower bound remains high in the future, the question of how monetary policy can re-anchor inflation expectations to the target level without conventional tools becomes an increasingly important issue for central banks around the world.

This paper investigates whether recent monetary policies in Japan, raising inflation target from 1 percent to 2 percent in January 2013 and introducing the unconventional policy framework called Quantitative and Qualitative Monetary Easing (QQE) in April 2013, contributed to re-anchoring long-run inflation expectations. In comparison with other major countries, Japan has been suffering from deflation and low inflation expectations for a much longer time. Since the end of 1990s, the Bank of Japan (BOJ) has used a variety of unconventional measures to overcome chronic deflation. Of such measures, raising the inflation target and introducing QQE are especially unique in that they were the first attempt in the world to re-anchor inflation expectations to a higher level when the policy rate was constrained at the effective lower bound. As the re-anchoring of inflation expectations without conventional measures can be a realistic challenge for other central banks, analyzing the Japanese experience will provide some important lessons.

We use *ESP Forecast*, a panel dataset of professional forecasts about the Japanese economy, to estimate the evolution of long-run inflation expectations. *ESP Forecast* includes monthly forecasts of annual inflation reported by around 40 Japanese professionals. Using this series from 2005 to 2017, we estimate the inflation expectations curves based on the dynamic Nelson-Siegel model (Nelson and Siegel (1987), Diebold et al. (2006)). Employing the dynamic Nelson-Siegel model in our analysis offers the following two advantages.

The first advantage is related to the characteristics of our dataset. *ESP Forecast* collects "fixed-event" forecasts, in which the forecast event is kept fixed in consecutive periods while the forecast horizon shrinks as time gets closer to the realization of that event. In each month, forecasters report their forecasts of annual inflation rates for the current, next, and following fiscal year until the realized value of target is released to the public.[1] In contrast to the "fixed-horizon" type survey, which collects the forecasts for a constant period (e.g., 1 year) ahead, the "fixed-event" dataset contains information about inflation expectations of a wide range of horizons (e.g., 1 month to 35 months in our data). At the same time, however, there is also a missing observations problem in the sense that forecasts with only two or three different horizons are reported in each month.[2] The dynamic Nelson-Siegel model has been widely used for fitting the term structure of interest rates, as it provides a flexible way of interpolation and extrapolation to estimate yields for any maturities that are not directly observable in data. We take advantage of this feature in the context of inflation expectations and evaluate the term structure of inflation expectations at any horizon and at any date, even though forecast targets in the survey data are limited to fixed events.

The second advantage is related to our objective. To investigate whether the policy suc-

[1] Many widely used surveys have the same structure, including *Consensus Forecasts* by Consensus Economics, *World Economic Outlook* by the International Monetary Fund, and the *OECD Economic Outlook.*

[2] For example, if the forecast date is October, forecasters report only 6, 18, and 30 months ahead forecasts.

ceeds in inducing a regime change in the anchoring of long-run inflation expectations, we aim to capture common variations in inflation expectations among all individual forecasters. By estimating a panel version of the dynamic Nelson-Siegel model, we can decompose individual inflation forecasts into fixed effects, three latent factors (level, slope, and curvature), and measurement errors. Three latent factors represent the common sources of variations while the fixed effects and the measurement errors control cross-sectional heterogeneity. Among three factors, the level factor corresponds to the notion of inflation expectations at the infinite horizon, and we can evaluate the policy effect on the long-run inflation expectations as a mean shift of the level factor. In terms of adopting the dynamic Nelson-Siegel model to inflation forecasts from survey data, our approach is similar to that of Aruoba (2020). However, it should be noted that Aruoba (2020) estimates the dynamic Nelson-Siegel model using the time series of aggregated inflation forecasts from several kinds of surveys that have a varied range of forecast horizons. In contrast, we estimate the model using a panel of non-aggregated individual forecasts from a single survey.

We find that the introduction of QQE in April 2013, rather than raising the inflation target to 2 percent in January 2013, actually made a significant impact on the expectation formation process of professional forecasters in Japan. Our estimate suggests that the cross-sectional average of long-run inflation expectations increased for 0.50 percent between three months before and after the introduction of QQE (from 0.14 percent to 0.64 percent). In contrast, when we use a same six-month window around the timing of raising the inflation target, the size of the shift is only 0.17 percent (from 0.11 percent to 0.28 percent). After the introduction of QQE, long-run inflation expectations, which had previously been around 0 percent, increased to a maximum level at 1.18 percent by the first half of 2014. In mid-2014, however, long-run expectations began to decline along with the sharp drop in oil prices. In fact, a series of sizable negative shocks to long-run expectations are observed between mid-2014 to early-2016, the period in which oil price continued to fall. Since our estimate suggests a high degree of intrinsic persistence of long-run expectations in Japan, it takes time for long-run expectations to move back to the steady state when large negative shocks occur. On the other hand, our estimate also suggests the reduction of correlation between short-run and long-run expectations since the introduction of QQE. In previous studies, the low correlation between short-run and long-run expectations has often been used as evidence of anchoring. Overall, our result implies that inflation expectations in Japan have been "re-anchored" to the level around 1 percent since the introduction of QQE, while the level is still short of the 2 percent target.

Our finding highlights three possible lessons for central banks, which may confront the future challenge of "re-anchoring" inflation expectations without relying on the conventional tools. First, monetary policy can be effective in raising long-run inflation expectations even though the short-term policy rate is constrained. With the introduction of QQE in April 2013, the BOJ started to strengthen monetary easing by purchasing a substantial amount of longer term government bonds, along with other assets such as ETF and J-REIT. In addition, the BOJ strongly committed to continue such asset purchases until the target of 2 percent inflation was achieved. The BOJ also stated that QQE would include all the measures necessary to achieving the 2 percent target within a time horizon of about two years. Such substantial and rapid monetary easing, along with aggressive forward guidance succeeded in raising long-run inflation expectations to the higher level, even though the policy rate was constrained at the effective lower bound. Second, an announcement of a higher inflation target itself does not guarantee the re-anchoring of inflation expectations. Both a structural break test and the estimation of the dynamic Nelson-Siegel model imply that a shift of long-run inflation expectations occurred in April 2013, not in January 2013. Indeed, in January 2013, the BOJ simply declared that it would "pursue monetary easing to achieve the target at the earliest possible time," without announcing any specific monetary easing scheme. This fact, combined with our results, suggests that only raising the inflation target was not sufficient and that specific actions towards the new target were needed to re-anchor inflation expectations. The lesson may be useful for central banks that consider increasing their inflation targets in the future. Third, central banks should pay careful attention to the dynamic properties of long-run inflation expectations and take quick policy actions in response to a sign of de-anchoring in the case of highly persistent inflation expectations. If the degree of intrinsic persistence of long-run expectations is high, as is the case in Japan, negative shocks can induce a deviation from the target for considerable periods of time. In particular, the reduction of the observed inflation rate caused by some exogenous factors, such as drops in oil prices, may have long-lasting effects on long-run inflation expectations. Under such circumstances, the timely implementation of effective policies, such as strong commitments and unconventional asset purchases, are desirable.

The remainder of the paper is organized as follows. Section 2 briefly reviews a recent experience of monetary policy in Japan and discusses the related literature. Section 3 describes our dataset and the model. Section 4 reports the empirical results. Section 5 concludes.

2 Background

2.1 Japanese Experience

1990s-2007 (Pre-Crisis Period)

In response to prolonged deflation in the 1990s, the BOJ introduced the zero interest rate policy in February 1999, which fixed the nominal interest rate at virtually 0 percent. At the same time, the BOJ explicitly committed to keep it "until deflationary concern is dispelled." In March 2001, the BOJ adopted a new unconventional monetary easing framework called Quantitative Easing, where the main operating target of monetary policy was shifted to the current account balance at the BOJ. The BOJ committed to continuing this policy "until the annual rate of change in the consumer price index registers zero percent or above in a stable manner." Although the BOJ implemented such novel monetary policy tools, the mild deflation and weak growth of the economy continued in the first half of 2000s.

Against the improved economic performance in late 2005, the BOJ decided to exit from Quantitative Easing and the zero interest rate in March 2006. The standard uncollateralized overnight rate was reintroduced as the operating target of monetary policy and raised from 0 percent to 0.25 percent in July 2006, and further, to 0.5 percent in February 2007. At the same time, to guide inflation expectations of private agents in Japan, the BOJ started to report the level of the inflation rate, which was recognized as price stability by each Policy Board member, in an annual survey called "understanding of medium to long-term price stability." From 2006 to 2011, the reported level varied across the Policy Board members but the midpoint of the range was always about 1 percent. Therefore, one may want to interpret 1 percent as the BOJ's implicit inflation objective during this period. However, the BOJ at that time repeatedly stressed that it was neither an inflation target nor inflation objective.

2008-2012 (Post-Crisis Period)

After the global financial crisis in 2008, exports to overseas economies declined and Japan encountered a severe recession in the deflationary regime. While the BOJ immediately reduced the policy interest rate in response to the collapse of Lehman Brothers in the fall of 2008, Japan's room for further monetary easing in the conventional way was limited. Such an environment led the BOJ to introduce the Comprehensive Monetary Easing policy in October 2010. In particular, the policy rate was set to zero again and the BOJ committed to maintaining the zero interest rate "until it judges that price stability is in sight on the basis of the understanding of medium to long-term price stability." In addition to this measure, the BOJ tried to reduce longer-term interest rates instead of constrained short-term policy rates by purchasing various financial assets, such as Japanese government bonds, corporate bonds, and ETF.

In February 2012, the BOJ introduced for the first time the explicit inflation target of 1 percent. In particular, it replaced the previous "understanding of medium to long-term price stability" with a "price stability goal in the medium to long-term." While the former simply reported the range of views about a desirable inflation rate held by Policy Board members, the latter was set as a consensus among all members of the Policy Board. The "price stability goal" was set to "a positive range of 2 percent with a midpoint of around 1 percent for the time being," but also would be reviewed once a year.

Although the BOJ tried to maintain accommodative financial conditions through the asset purchase and forward guidance, the CPI inflation rate in Japan remained either negative or fluctuated at around 0 percent at the end of 2012. Against this background, the BOJ decided to raise the inflation target from 1 percent to 2 percent in January 2013. In the announcement, the BOJ declared that it would pursue monetary easing and aim to achieve the target at the earliest possible time. On the other hand, it refrained from introducing a specific monetary easing program at that point in time.

2013-present (QQE Period)

As a concrete means of achieving the inflation target of 2 percent at the earliest possible time, the BOJ introduced a new unconventional monetary policy framework called QQE in April 2013. In the introduction of QQE, the main operating target of monetary policy was shifted from the policy rate to the monetary base. The BOJ promised to increase the monetary base at an annual pace of about 60 to 70 trillion yen, and the amount of Japanese government bonds purchased were substantially increased, compared to the period of Comprehensive Monetary Easing. In addition to such "quantitative" accumulations, the BOJ also tried to utilize a "qualitative" device. In particular, the BOJ extended the average remaining maturity of bond purchases from about three years to seven years by preferentially purchasing long-term bonds with maturities up to 40 years. Furthermore, the BOJ introduced the forward guidance policy regarding asset purchases so that the QQE would be continued as long as the BOJ would deem it necessary for maintaining the price stability target in a stable manner. The BOJ also declared that QQE would include all the necessary measures to achieve the target of 2 percent within a time horizon of about two years.

Since the 1990s, Japan had almost never experienced as much as 2 percent inflation. At the time QQE was introduced, Japan had been suffering from prolonged deflation for more than a decade. In this respect, the challenge of QQE was truly "unprecedented (Kuroda (2015))." The main concern of the BOJ has been the possibility that the past experience of chronic deflation inclines households and firms to form strong deflationary expectations, reduce consumption and investment, and cause further deflation in a self-fulfilling manner. Therefore, the aim of QQE was "to dispel the deflationary mindset and raise inflation expectations (Kuroda (2015))." Compared to Quantitative Easing in 2001 and Comprehensive Monetary Easing in 2010, QQE in 2013 was distinctive in the sense that the anchoring of long-run inflation expectations was explicitly treated as a central objective and a key transmission mechanism of the policy.

In response to a sharp drop in oil prices that caused a decline in inflation in mid-2014, the BOJ decided to expand QQE in October 2014. The annual pace of increase in the monetary base was accelerated and the average remaining maturity of government bond purchases was extended to about 7 to 10 years. Nevertheless, inflation rates remained significantly below the target in 2015, partly due to a further decline in oil prices. In January 2016, the BOJ introduced QQE with a Negative Interest Rate policy by adopting a -0.1 percent interest rate on part of the excess reserves. At the same time, the average remaining maturity of government bond purchases was further extended to 7 to 12 years. In September 2016, the BOJ introduced QQE with Yield Curve Control, which mainly consists of two parts. The first part is called the "yield curve control," which aims to control long-term interest rates through market operations. The second part is called "inflation-overshooting commitment" in which the BOJ commits itself to expanding the monetary base until the inflation rate exceeds the 2 percent target and stays above the target in a stable manner. It should be noted that, while several variations of QQE had been introduced over the past few years, the anchoring of long-run inflation expectations remained a central objective of QQE.

In summary, recent monetary policies in Japan are noteworthy in that it used unconventional tools to raise inflation expectations from a level substantially below the target.[3] We believe that analyzing the effects of such a policy will provide some important lessons to other central banks.

2.2 Related Literature

Time Series Analysis of Inflation Expectations Survey Data

Our paper is related to the previous studies that adopt the dynamic Nelson-Siegel model to inflation expectations. The paper most similar to ours is Aruoba (2020), who estimates the term structures of inflation expectations and real interest rates in the United States. Lewis and McDermott (2016) also employ a similar approach to Aruoba (2020) and examine the effect of the past changes in the inflation target by the Reserve Bank of New Zealand. There are also other studies that estimate the term structure of inflation expectations from survey data but with different methodologies. Kozicki and Tinsley (2012) propose the shifting-endpoint autoregressive (AR) model to jointly explain inflation and inflation expectations. Winkelried (2017) modifies the shifting-endpoint AR model to fit the fixed-event forecast

[3] About the difficulties of anchoring inflation expectations when the central banks are targeting inflation from below, see Ehrmann (2015).

data. A similar strategy is also taken by Mehrotra and Yetman (2018). These studies explicitly assume that inflation evolves according to an AR process and inflation expectations are formed as efficient and unbiased predictors. Inflation forecasts are assumed to eventually converge to the point called the "shifting-endpoint" (in Kozicki and Tinsley (2012)) or the "anchor" (in Mehrotra and Yetman (2018)) as the forecast horizon increases. It should be noted that these concepts correspond to the level factor in the dynamic Nelson-Siegel model. Since our objective is to extract common variations in inflation expectations of individual forecasters, we do not need to specify how forecasters form their expectations nor what information set they use.

Anchoring of Inflation Expectations

There is a growing literature examining the anchoring of inflation expectations. Gürkaynak et al. (2010) compare long-run inflation expectations in several countries by using the difference between forward rates on nominal and inflation-indexed bonds. Beechey et al. (2011) combine financial market data and survey data to examine the anchoring of inflation expectations in the euro area and the United States. Galati et al. (2011) also use financial market data to investigate whether the global financial crisis in 2008 affected inflation expectations in the United States, the euro area, and the United Kingdom. Ehrmann (2015) uses survey data in the countries adopting inflation targeting and argues that de-anchoring of inflation expectations is likely to occur under persistently low inflation compared to situations where inflation is around the target. Autrup and Grothe (2014) find that the degree of anchoring of inflation expectations in the United States decreased by the outbreak of the crisis. In addition, Nautz and Strohsal (2015) report that expectations in the United States have not been re-anchored ever since. Buono and Formai (2018) find that inflation expectations have been firmly anchored at the target in the United States but de-anchored in the euro area and Japan. Grishchenko et al. (2019) and Corsello et al. (2019) also report that de-anchoring has occurred in the euro area.

Empirical Analysis of QQE

Several researchers recently examined the effect of QQE on inflation expectations in Japan. Using survey data of Japanese households, Nishiguchi et al. (2014) report that more households have forecasted price increases than price declines and that the distribution of their expectations has shifted in the inflationary direction after the introduction of QQE. Kamada et al. (2015) use the same dataset as Nishiguchi et al. (2014) and conclude that QQE actually strengthened the anchor of long-term inflation expectations. In contrast, Nakazono (2016) argues that recent monetary policies in Japan may have not been sufficient to change the private sector's outlook for future inflation, according to various surveys for households, firms, professionals and market participants. Hattori and Yetman (2017) adopt the model of Mehrotra and Yetman (2018) to *Consensus Forecasts* data from Consensus Economics and report that long-run inflation expectations in Japan fell from the mid-1990s but have risen in recent years. Hogen and Okuma (2018) estimate a model of expectations formation proposed by Carvalho et al. (2017) and conclude that inflation expectations in Japan temporarily increased after QQE but have not yet been anchored to the 2 percent target. Maruyama and Suganuma (2020) combine various forecast data and estimate a system of equations that include the term structure of inflation expectations as a part of the system. They conclude that short-term inflation expectations increased since the introduction of QQE. Last but not least, in September 2016, the BOJ itself conducted the official assessment of QQE over the first three years following the introduction and reported it as a "Comprehensive Assessment" (Bank of Japan (2016a,b)). Our paper complements these papers by estimating long-run inflation expectations as common variations in individual inflation forecasts reported by professional forecasters.

3 Data and Model

3.1 Data

ESP Forecast is a monthly survey of the macroeconomic forecasts, which has been conducted for more than fifteen years in Japan. One main advantage of *ESP Forecast* for our analysis is that all the participants are leading forecasters from private institutions in Japan, who are familiar with the Japanese economic environment and have regularly been involved in the Japanese financial market. Each month, about 40 forecasters are asked to provide their personal forecasts for macroeconomic and financial variables in Japan over the current, next, and following fiscal years.[4] The survey is conducted from the last week of a particular month to the first week in the next month. About a week after the collection of the survey, a formal monthly report is published by the Japan Center for Economic Research.

In our analysis, we use individual forecasts of annual inflation rates for the current, next, and following fiscal years from *ESP Forecast*. Inflation rates are based on the changes in the consumer price index of all items, less fresh foods. We construct a balanced panel of 28 forecasters for the sample period from April 2005 to March 2017. Figure 1 shows the distribution of individual inflation forecasts for four selected target fiscal years, 2007, 2010, 2013 and 2016. The horizontal axis denotes the forecast horizons. Dashed line and solid line represent realized values and median forecasts, respectively. The dots in the figure for a particular forecast horizon represent the individual inflation forecasts made at the same timing. Therefore, the range of dots for a given forecast horizon corresponds to a measure of disagreement. As the forecast horizon becomes shorter, disagreement among individual forecasts declines. Since *ESP Forecast* collects the "fixed-event" type of forecasts, the forecast event is kept fixed while the forecast horizon shrinks as time gets closer to the final month of the target fiscal year. The figure shows that, because of increasing information, their

[4] In Japan, the fiscal year is from April 1 to March 31.

forecasts eventually converge to the realized inflation rate.

Our intention is to investigate the effects of raising the inflation target to 2 percent in January 2013 and the introduction of QQE in April 2013 on long-run inflation expectations. As a preliminary analysis, we first examine whether these policies actually result in some changes in the inflation forecasts series. In particular, we apply multiple structural break tests proposed by Bai and Perron (1998, 2003) to the time series of the cross-sectional average of individual inflation forecasts. To construct a single time series, we pool the forecasts for the current, next, and following target fiscal years. Following the advice of Bai and Perron (2003), we first look to see if at least one break is present using the double maximum statistics, and then determine the number of breaks using the sequential procedure based on the $\sup F$ statistics.

Table 1 presents the results of the structure break test. For the double maximum statistics of Bai and Perron (1998), allowing for up to 5 breaks with a trimming fraction of 0.15, both $\mathrm{UD}_{\max}(= 451.78)$ and $\mathrm{WD}_{\max}(= 775.99)$ are above the corresponding critical values at the 1 percent significance level. Thus, the null hypothesis of no structural break is significantly rejected. The $\sup F$ test statistic for the null of no break against an alternative of 1 break ($F(1|0)$) and for the null of 1 break against an alternative of 2 breaks ($F(2|1)$) is 155.01 and 309.48, respectively. Again, at the 1 percent significance level, both the null hypotheses of no break and 1 break are rejected. In contrast, the $\sup F$ test statistic for the null of 2 breaks against an alternative of 3 breaks ($F(3|2)$) is 10.08 and less than the critical values at the 1 percent significance level. To summarize the results in Table 1, we can conclude that there are 2 breaks in the series of average inflation forecasts. Table 2 reports the estimated dates for 2 structural breaks and their 95 percent confidence intervals. The first break is in November 2008, which is soon after the bankruptcy of Lehman Brothers. The second break is in April 2013, which matches the timing when QQE was introduced by the BOJ. The latter result suggests that the regime change in inflation expectations formation in Japan occurred at the timing of the introduction of QQE and not at the timing of raising the inflation target in January 2013. In the table, the subsample means of the average inflation forecasts for three estimated regimes are also reported. The number suggests that the mean of the average inflation forecasts increased from -0.59 percent to 0.76 percent after the introduction of QQE.

Table 1: Bai and Perron (1998) Test for Multiple Structural Breaks in the Mean

$\mathrm{UD}_{\max}$	$\mathrm{WD}_{\max}(1\%)$	$F(1\|0)$	$F(2\|1)$	$F(3\|2)$
451.78	775.99	155.01	309.48	10.08
(7.46)	(13.83)	(12.29)	(13.89)	(14.8)

Notes : The critical values of test statistics at the 1 percent significance level are reported in parentheses.

Table 2: Bai and Perron (2003) Estimates of Mean Inflation Forecasts

Regime 1	Regime 2	Regime 3
0.46 (0.055)	-0.59 (0.049)	0.76 (0.060)
2008:11 [2008:06,2009:02]	2013:04 [2013:03,2013:07]	

Notes : The first row reports the estimated mean of inflation forecasts for each regime with the standard error in parentheses. The second row reports the end date for each regime with the 95% confidence interval in brackets.

3.2 Dynamic Nelson-Siegel Model

We denote the annual inflation rate of the target fiscal year by

$$\Pi_T = \frac{\pi_{T-11} + \cdots + \pi_T}{12}, \tag{1}$$

where π_t is the year-on-year monthly inflation rate at the month t and the uppercase letter T denotes the final month (March) of a target fiscal year. Given that the sample period is from April 2005 to March 2017, there are total of 12 target fiscal years and we can write $T = 12j$ for $j = 1, \cdots, 12$. Suppose that we now are at the period $t = T - h$, h months before the final month T of a particular target year ($t = 1, \cdots, 144, 1 \leq h \leq 35$). *ESP Forecast* then collects the forecast for (1), which we denote as

$$\Pi_{T|t=T-h} = \frac{\pi_{T-11|T-h} + \cdots + \pi_{T|T-h}}{12}, \tag{2}$$

where $\pi_{s|t}$ is the forecast for the monthly inflation at the period s made at the period t. It should be noted that since $\pi_{s|t} = \pi_s$ for $s \leq t$, (2) contains realized values of monthly inflation when $h \leq 11$.

Our objective is to extract the complete term structure of inflation expectations by using the observations (2). In particular, we need to compute the τ-month average inflation expectations from month $t + 1$ to $t + \tau$ denoted as

$$\bar{\pi}_t(\tau) = \frac{\pi_{t+1|t} + \cdots + \pi_{t+\tau|t}}{\tau} \tag{3}$$

as a function of τ. If (3) is directly observable for any length τ at any period t in the dataset, we can immediately achieve our objective. However, as in most other surveys, the reported inflation forecasts in *ESP Forecast* do not correspond exactly to (3). As we can see by comparing (2) and (3), the observed forecast $\Pi_{T|t=T-h}$ coincides the estimation target $\bar{\pi}_t(\tau)$ only when the forecast date t is exactly 12 months before T. At only this timing, the observable (2) becomes

$$\Pi_{T|t=T-12} = \frac{\pi_{T-11|T-12} + \cdots + \pi_{T|T-12}}{12}$$

and coincides with

$$\bar{\pi}_t(12) = \frac{\pi_{t+1|t} + \cdots + \pi_{t+12|t}}{12}$$

as $t = T - 12$. For almost all timings other than $h = 12$, we cannot directly observe the estimation target (3). To use all the observations and extract as much information as possible, we need a model to connect the observable (2) and the estimation target (3). To this end, we take a similar approach to that of Aruoba (2020) and use the dynamic Nelson-Siegel model. In particular, we assume that $\bar{\pi}_t(\tau)$ is generated from the process given by

$$\bar{\pi}_t(\tau) = L_t - \left(\frac{1 - e^{-\lambda\tau}}{\lambda\tau}\right) S_t + \left(\frac{1 - e^{-\lambda\tau}}{\lambda\tau} - e^{-\lambda\tau}\right) C_t, \tag{4}$$

where L_t, S_t, and C_t are time-varying level, slope, and curvature factors.

In the specification above, the level factor L_t can be expressed as

$$L_t = \lim_{\tau\to\infty} \bar{\pi}_t(\tau). \tag{5}$$

Thus, this level factor measures the long-run inflation expectations held by individual forecasters at time t. It also corresponds to the notion of the "shifting-endpoint" in Kozicki and Tinsley (2012) and that of the "anchor" in Mehrotra and Yetman (2018).

On the other hand, the slope factor S_t captures the difference between long-run and short-run inflation expectations, and the curvature factor C_t captures whether medium-run expectations are higher or lower than short-run expectations and long-run expectations. The parameter λ determines the effect of each factor on $\bar{\pi}_t(\tau)$ through factor loadings.

When $h > 11$ (i.e., $t < T - 11$), we use the definition (3) to rewrite (2) as

$$\begin{aligned}
\Pi_{T|t=T-h} &= \frac{h}{12} \times \frac{\pi_{T-h+1|T-h} + \cdots + \pi_{T|T-h}}{h} - \frac{h-12}{12} \times \frac{\pi_{T-h+1|T-h} + \cdots + \pi_{T-12|T-h}}{h-12} \\
&= \frac{h}{12}\bar{\pi}_{T-h}(h) - \frac{h-12}{12}\bar{\pi}_{T-h}(h-12) \\
&= \frac{h}{12}\bar{\pi}_{t}(h) - \frac{h-12}{12}\bar{\pi}_{t}(h-12),
\end{aligned} \tag{6}$$

where the last equality uses the fact that $t = T - h$. By substituting the model equation (4) to (6), we obtain

$$\Pi_{T|t=T-h} = L_t + \left(\frac{e^{-\lambda(h-12)} - e^{-\lambda h}}{12h}\right) S_t + \frac{1}{12}\left(\frac{e^{-\lambda(h-12)} - e^{-\lambda h}}{\lambda} + (h-12)e^{-\lambda(h-12)} - he^{-\lambda h}\right) C_t. \tag{7}$$

When $h \leq 11$ (i.e., $t \geq T - 11$), the forecast date t is within one year before the final month of the target fiscal year. Using the fact that

$$\pi_{T-11|T-h} = \pi_{T-11}, \ \cdots, \ \pi_{T-h|T-h} = \pi_{T-h},$$

hold for $h \leq 11$, (2) can be decomposed as

$$\begin{aligned}
\Pi_{T|t=T-h} &= \frac{\pi_{T-11} + \cdots + \pi_{T-h} + \pi_{T-h+1|T-h} + \cdots + \pi_{T|T-h}}{12} \\
&= \frac{\pi_{T-11} + \cdots + \pi_{T-h}}{12} + \frac{h}{12}\bar{\pi}_{T-h}(h) \\
&= \frac{\pi_{t+h-11} + \cdots + \pi_{t}}{12} + \frac{h}{12}\bar{\pi}_{t}(h).
\end{aligned} \tag{8}$$

By substituting the model equation (4) to (8), we obtain

$$\frac{12}{h}\left(\Pi_{T|t=T-h} - \frac{\pi_{t+h-11} + \cdots + \pi_t}{12}\right) = L_t - \left(\frac{1 - e^{-\lambda h}}{\lambda h}\right) S_t + \left(\frac{1 - e^{-\lambda h}}{\lambda h} - e^{-\lambda h}\right) C_t. \tag{9}$$

Based on (7) and (9), we set the measurement equations as

$$\begin{cases} \Pi^{i,ESP}_{T|t} = c_i + L_t + \left(\frac{e^{-\lambda(h-12)} - e^{-\lambda h}}{12\lambda}\right) S_t + \frac{1}{12}\left(\frac{e^{-\lambda(h-12)} - e^{-\lambda h}}{\lambda} + (h-12)e^{-\lambda(h-12)} - he^{-\lambda h}\right) C_t + \varepsilon^i_{t,h}, \\ (\text{if } t < T-11) \\ \\ \frac{12}{h}\left(\Pi^{i,ESP}_{T|t} - \frac{\pi_{t+h-11} + \cdots + \pi_t}{12}\right) = c_i + L_t - \left(\frac{1-e^{-\lambda h}}{\lambda h}\right) S_t + \left(\frac{1-e^{-\lambda h}}{\lambda h} - e^{-\lambda h}\right) C_t + \varepsilon^i_{t,h}, \\ (\text{if } t \geq T-11) \end{cases} \tag{10}$$

where $\Pi^{i,ESP}_{T|t}$ denotes the forecast corresponding to (2) reported by the forecaster i at the period t in *ESP Forecast*. We introduce an idiosyncratic fixed effect c_i, which captures the time-invariant heterogeneity of inflation expectations among individual forecasters. On the other hand, L_t, S_t, and C_t capture the dynamics of unobserved factors, which induce common variations in inflation expectations. All deviations of the observed inflation forecasts from the model predictions are captured by the measurement error $\varepsilon^i_{t,\tau} \sim N(0, \sigma^2_\tau)$.

The three latent factors are assumed to follow the independent AR processes of order p given by

$$\begin{aligned} L_t &= \mu_L + \rho_{11}(L_{t-1} - \mu_L) + \cdots + \rho_{1p}(L_{t-p} - \mu_L) + \eta^L_t, \\ S_t &= \mu_S + \rho_{21}(S_{t-1} - \mu_S) + \cdots + \rho_{2p}(S_{t-p} - \mu_S) + \eta^S_t, \\ C_t &= \mu_C + \rho_{31}(C_{t-1} - \mu_C) + \cdots + \rho_{3p}(C_{t-p} - \mu_C) + \eta^C_t, \end{aligned} \tag{11}$$

where $\eta^j_t \sim N(0, \sigma^2_j)$ and $Cov(\eta^j_t, \eta^k_{t-s}) = 0$ for $j, k = L, S$, and C, and $s \geq 0$. The lag-order p is chosen by minimizing information criteria. We also consider the vector autoregressive (VAR) specification as an alternative to (11). Given the result of the structural break test, we allow the long-run average of the level factor μ_L to change over the three periods: before November 2008, from November 2008 to March 2013, and after April 2013, which corresponds to the timing of the introduction of QQE. We also consider the case when April

2013 is replaced by January 2013, which corresponds to the timing of raising the inflation target from 1 percent to 2 percent.

In the next section, a state space model, which consists of the measurement equations (10) and the transition equations (11), is estimated by using maximum likelihood combined with the Kalman filter. While there are missing observations in our dataset due to the structure of the survey, the Kalman filter and the state space model are well suited to handle them. The three factors, L_t, S_t, and C_t, are estimated using the Kalman smoother. A total of $71 + 3p$ parameters are estimated, where 35 of them are measurement error variances $\sigma_1^2, \cdots, \sigma_{35}^2$.

4 Estimation Results

Table 3 reports the AIC and BIC for the model with AR(1), AR(2), AR(3), and VAR(1) transition equations. The upper panel shows the results under the assumption that the second mean shift occurred in January 2013, which corresponds to the timing of raising the inflation target. The lower panel shows the results under the assumption that the second mean shift occurred in April 2013, which corresponds to the timing of the introduction of QQE. As the table suggests, the AR(2) model with the mean shift in April 2013 is the preferred specification based both on AIC and BIC.[5]

Panel (a) of Table 4 shows the estimated parameters of the selected specification, which we call the benchmark model. The level factor L_t has a mean of 0.56 percent before November 2008 ($\mu_{L,1}$ in Panel (a) of Table 4), -0.42 percent from November 2008 to March 2013 ($\mu_{L,2}$), and 0.87 percent after April 2013 ($\mu_{L,3}$).[6] The sum of the AR coefficients of the level factor is 0.92 ($= 1.44 + (-0.52)$), suggesting that long-run inflation expectations are intrinsically

[5] We also estimate a version of the model which allows the contemporaneous correlation among AR disturbances of the three factors using the non-diagonal covariance matrix. All the estimates of the non-diagonal terms of the covariance matrix are insignificant and the estimates of the other parameters are almost the same as the benchmark model.

[6] For identification of the mean parameter of the level factor, we normalize the sum of fixed effects $\sum_{i=1}^{28} c_i$ to be 0. The model without fixed effects c_i's is not selected since AIC = 948.95 and BIC = 1097.44.

Table 3: Model Selection Criteria

	Model			
	AR(1)	AR(2)	AR(3)	VAR(1)
January 2013 (inflation target change)				
AIC	368.70	343.01	651.75	659.18
BIC	588.37	571.69	887.80	896.65
April 2013 (introduction of QQE)				
AIC	358.00	331.79	642.36	647.21
BIC	577.76	560.47	879.94	884.80

Notes : AR(1), AR(2), and AR(3) specifications impose the independence of error terms of three factors.

persistent. The slope factor S_t, which represents the difference between long-run and short-run inflation expectations, has a mean of 0.32 percent. The curvature factor C_t has a mean of 0.98 percent, which suggests that medium-run expectations are typically higher than short-run expectations and long-run expectations, and that the inflation expectations curve is mildly inverse-U shaped on average.

Panel (b) of Table 4 shows the estimated parameters of the measurement equations. The estimated value of parameter λ is 0.060, suggesting that the loading on the curvature factor is maximized at a forecast horizon of 52 months. Panel (b) also contains the estimated variances of the measurement errors. On the whole, the variances are relatively small, given the unit of dependent variable, namely the annual inflation expectations.

Figure 2 presents the smoothed estimates of the three latent factors. The level factor sharply drops from over 1 percent to the negative area soon after the global financial crisis in 2008. It recovers to be slightly positive over the next two periods, but still fluctuates around 0 percent until 2013. After the introduction of QQE, it steadily increases and reaches about 1.18 percent at the highest. The slope and curvature factors are positive for most of the periods. The slope declines soon after the introduction of QQE but starts to increase at the beginning of 2014. It implies that the difference between long-run and short-run inflation

Table 4: Estimation Results: Benchmark Model

(a) Transition equation

Level		Slope		Curvature	
ρ_{11}	1.44	ρ_{21}	0.88	ρ_{31}	1.51
	(0.19)		(0.17)		(0.39)
ρ_{21}	−0.52	ρ_{22}	0.004	ρ_{32}	−0.59
	(0.17)		(0.17)		(0.36)
$\mu_{L,1}$	0.56	μ_S	0.32	μ_C	0.98
	(0.26)		(0.18)		(0.90)
$\mu_{L,2}$	−0.42				
	(0.27)				
$\mu_{L,3}$	0.87				
	(0.38)				
σ_L^2	0.009	σ_S^2	0.04	σ_C^2	0.073
	(0.002)		(0.01)		(0.072)

(b) Measurement equation

		λ	0.060		
			(0.011)		
σ_1^2	0.012	σ_{13}^2	0.041	σ_{25}^2	0.054
	(0.0018)		(0.0030)		(0.0087)
σ_2^2	0.010	σ_{14}^2	0.040	σ_{26}^2	0.077
	(0.0011)		(0.0036)		(0.0081)
σ_3^2	0.015	σ_{15}^2	0.047	σ_{27}^2	0.073
	(0.0018)		(0.0057)		(0.020)
σ_4^2	0.009	σ_{16}^2	0.058	σ_{28}^2	0.087
	(0.0009)		(0.0098)		(0.012)
σ_5^2	0.015	σ_{17}^2	0.063	σ_{29}^2	0.118
	(0.0018)		(0.0086)		(0.016)
σ_6^2	0.023	σ_{18}^2	0.073	σ_{30}^2	0.085
	(0.0029)		(0.0120)		(0.010)
σ_7^2	0.013	σ_{19}^2	0.059	σ_{31}^2	0.113
	(0.0014)		(0.0096)		(0.018)
σ_8^2	0.040	σ_{20}^2	0.057	σ_{32}^2	0.123
	(0.0031)		(0.012)		(0.015)
σ_9^2	0.066	σ_{21}^2	0.066	σ_{33}^2	0.099
	(0.0063)		(0.019)		(0.016)
σ_{10}^2	0.071	σ_{22}^2	0.093	σ_{34}^2	0.085
	(0.0067)		(0.022)		(0.026)
σ_{11}^2	0.092	σ_{23}^2	0.132	σ_{35}^2	0.145
	(0.0063)		(0.0071)		(0.013)
σ_{12}^2	0.033	σ_{24}^2	0.059		
	(0.0039)		(0.0080)		

Notes : Standard errors in parentheses.

expectations starts to widen during this period, which roughly coincides with the start of the sharp drop in oil prices. In the later subsection, we will discuss this point in greater detail.

Inflation Expectations Curve and Long-run Inflation Expectations

Once we estimate all the parameters and latent factors, we can draw the inflation expectations curve, which is useful to see the term structure of inflation expectations at the given period. Figure 3 compares the estimated inflation expectations curves at three months before and after the introduction of QQE in April 2013. In the figure, each solid line represents the inflation expectation held by each individual forecaster. As pointed out in the previous subsection, medium-run expectations are higher than short-run and long-horizon expectations in both periods, which leads to mild inverse-U shaped inflation expectations curves. The figure shows that inflation expectations at all horizons increase at the same time after the introduction of QQE. On the other hand, Figure 4 shows the result of the similar comparison at the timing of raising the inflation target in January 2013. As the figure shows, there is little change in long-run inflation expectations, while short-run inflation expectations decline a bit rather than increase.

Let us now turn to the evolution of the long-run expectations, the level to which the individual forecaster believes that future inflation will eventually converge as the forecast horizon increases to infinity. Figure 5 shows the estimated individual long-run inflation expectations, $c_i + L_t$. As in Figure 3, each solid line represents the inflation expectation held by each individual forecaster. The result here implies that the introduction of QQE in April 2013, rather than raising the inflation target in January 2013, actually made a significant impact on the expectation formation process of professional forecasters in Japan. In comparing the timing of three months before and after the introduction of QQE, we see that the cross-sectional average of estimated long-run inflation expectations changes from 0.14 percent to 0.64 percent. In contrast, when a similar comparison is made at the timing of raising the inflation target, the change is much smaller (from 0.11 percent to 0.28 percent).

The dotted line in Figure 5 plots the realized monthly year-on-year inflation rate (all items, less fresh foods). While the change in the long-run expectations is modest compared to that of the actual inflation, they basically move closely at least until the introduction of QQE. In response to the surge in the short-term realized inflation around the first half of 2008, inflation expectations reached the highest level of 1.5 percent. However, the rise in expectations was completely wiped out by the occurrence of Lehman shock and the subsequent global financial crisis. Afterwards, both realized inflation and inflation expectations remained negative for awhile. Although the BOJ first introduced the formal inflation target of 1 percent in February 2012 and raised it to 2 percent in January 2013, the monthly inflation rate and long-run expectations fluctuated around 0 percent during this period.

Immediately after the introduction of QQE, both the realized monthly inflation rate and long-run inflation expectations rose sharply. The rise in inflation expectations remained steady at least until the first half of 2014. However, soon after the drop in oil prices in mid-2014, the growth slowed down and monthly inflation also fell significantly at the same time. After 2015, the long-run inflation expectations finally started declining and fell further in January 2016.

In the "Comprehensive Assessment" (Bank of Japan (2016a,b)), the BOJ argues that as a result of QQE, "economic activity and price developments improved, and Japan's economy is no longer in deflation." However, at the same time, the BOJ acknowledges that "the price stability target of 2 percent has not been achieved" and argues that it is "largely due to developments in inflation expectations." The BOJ points out that "expectations formation in Japan is largely adaptive, that is, backward-looking" in the sense that it is strongly influenced by the course of the past inflation rate. In summary, the BOJ takes the view that the combination of the adaptive expectation formations of Japanese private agents and decline in the observed inflation rate due to exogenous factors, including the sharp decline in oil prices since mid-2014, resulted in weakened inflation expectations.[7]

In our analysis, the estimated dynamics of long-run inflation expectations can be used to support the BOJ's explanations in the "Comprehensive Assessment." Figure 6 shows the estimated time series of the exogenous shocks to the level factor (η_t^L in (11)) after the introduction of QQE. The shaded area shows the periods of oil price decline.[8] Large negative shocks to the level factor occurred in January 2015, May 2015, and February 2016. Since the long-run inflation expectations in Japan are intrinsically persistent, these negative exogenous shocks had long-lasting effects. One interpretation would be, as the BOJ explained in the "Comprehensive Assessment," that the sharp instances of decline in the observed inflation rates become negative exogenous shocks to the long-run inflation expectations of individual forecasters.

Anchoring of Inflation Expectations

It is known that the correlation between short-run and long-run inflation expectations can be an indicator for the degree of inflation expectations anchoring.[9] Suppose that now there is a temporal shock to the current inflation rate. If inflation expectations are well-anchored and forecasters expect such shocks to disappear soon, only the short-run expectations should be affected, and medium- to long-run expectations should change only slightly. In the extreme case, if the forecasters believe that future inflation will eventually converge to the central bank's inflation target no matter what happens, fluctuations in short-run expectations should be completely unrelated to long-run expectations. On the contrary, if inflation expectations are "de-anchored," the exogenous shock induces fluctuations in medium to long-run expec-

[7]As to the other exogenous factors to have possibly affected inflation expectations in these periods, the BOJ refers to the weakness in demand following the consumption tax hike in April 2014 and the slowdown in emerging economies since mid-2015.

[8]Following Kilian and Baumeister (2016), we set the period from June 2014 to March 2016.

[9]For the comprehensive discussion of the method to assess the anchoring of inflation expectations, see Kumar et al. (2015) and Bems et al. (2018).

tations, and even the expectations of the distant horizon should change significantly in the same direction as short-run expectations. In that sense, comovements between short-run and long-run inflation expectations can be one of the indicators for the degree of inflation expectations anchoring.

Figure 7 shows the time series of the cross-sectional mean of the estimated inflation expectations at several selected horizons: 1-month, 1-year, 2-year, and 5-year. The eyeball analysis of the figure suggests that the correlation between short-run and long-run inflation expectations seems to become weaker in the third regime than in the second regime. Thus, we can conjecture that the anchoring of inflation expectations became stronger in the third regime. In what follows, we formally investigate the degree of anchoring by using the extended version of the dynamic Nelson-Siegel model.

We consider a simple extension of the benchmark model to allow not only the mean μ_L but also the conditional volatility of the level factor σ_L^2 to vary over the three regimes. The result is summarized in Table 5.[10] The estimated mean and persistence of each factor are almost the same as the benchmark case. As a result, the evolution of the estimated long-run inflation expectations is almost the same as shown in Figure 8. The conditional volatility of the level factor is 0.005 in the first regime ($\sigma_{L,1}^2$ in Panel (a)), 0.021 in the second regime ($\sigma_{L,2}^2$), and 0.002 in the third regime ($\sigma_{L,3}^2$).

Allowing the shift in the conditional volatility of the level factor in the extended model provides us with two additional implications on the properties of long-run inflation expectations. First, the result suggests that the uncertainty of long-run inflation expectations declines after the introduction of QQE. While monitoring whether the level of inflation expectations is in line with the inflation target is the widely used indicator of the degree of anchoring, policymakers may also pay attention to the uncertainty of long-run inflation expectations. As Grishchenko et al. (2019) argue, the level of long-run inflation expectations

[10] For brevity, we omit the estimated variances of the measurement errors from the table.

can remain stable at some point, even if uncertainty of expectations is relatively high. When the uncertainty of inflation expectations is higher, agents in the economy expect higher upside or downside risks to future inflation, leading to a higher probability that inflation expectations will be de-anchored when exogenous shocks occur in the future. Our estimates suggest that such a probability has been reduced with the introduction of QQE.

Table 5: Estimation Results: Extended Model

(a) Transition equation

Level		Slope		Curvature	
ρ_{11}	1.52	ρ_{21}	0.86	ρ_{31}	1.37
	(0.20)		(0.19)		(0.46)
ρ_{21}	−0.59	ρ_{22}	0.022	ρ_{32}	−0.42
	(0.19)		(0.18)		(0.44)
$\mu_{L,1}$	0.50	μ_S	0.35	μ_C	1.01
	(0.24)		(0.20)		(0.90)
$\mu_{L,2}$	−0.42				
	(0.75)				
$\mu_{L,3}$	0.87				
	(0.19)				
$\sigma^2_{L,1}$	0.005	σ^2_S	0.05	σ^2_C	0.10
	(0.003)		(0.01)		(0.099)
$\sigma^2_{L,2}$	0.021				
	(0.006)				
$\sigma^2_{L,3}$	0.002				
	(0.001)				

(b) Measurement equation

λ	0.060
	(0.009)

Notes : Standard errors in parentheses.

Second, as we previously mentioned, the correlation between short-run and long-run inflation expectations can be an important indicator for the degree of inflation expectations anchoring. To investigate the anchoring of inflation expectations, several studies (Kumar et al. (2015), Strohsal et al. (2016), Buono and Formai (2018) and Yetman (2020)) utilize the following type of regression

$$\bar{\pi}_t(\tau) = \alpha_\tau + \beta_\tau \pi_{t+1|t} + e_{\tau t}. \quad (12)$$

In this regression, the smaller β_τ implies the lower path-through from short-run expectations to long-run expectations and thus the higher degree of anchoring. Kumar et al. (2015) refer to such a regression analysis as the test of "increasingly anchored" inflation expectations.[11] In our model, the coefficient β_τ is related to the variance of the three factors. Indeed, β_τ in our model can be calculated as

$$\begin{aligned} \beta_\tau &= \frac{Cov(\bar{\pi}_t(\tau), \pi_{t+1|t})}{Var(\pi_{t+1|t})} \\ &= \frac{Var(L_t) + \left(\frac{1-e^{-\lambda\tau}}{\lambda\tau}\right)\left(\frac{1-e^{-\lambda}}{\lambda}\right) Var(S_t) + \left(\frac{1-e^{-\lambda\tau}}{\lambda\tau} - e^{-\lambda\tau}\right)\left(\frac{1-e^{-\lambda}}{\lambda} - e^{-\lambda}\right) Var(C_t)}{Var(L_t) + \left(\frac{1-e^{-\lambda}}{\lambda}\right)^2 Var(S_t) + \left(\frac{1-e^{-\lambda}}{\lambda} - e^{-\lambda}\right)^2 Var(C_t)}, \end{aligned} \quad (13)$$

where we use the fact that the factors are assumed to be mutually independent. As can be seen from the above calculation, the decline in the conditional volatility of the level factor in our specification directly leads to the decline in the coefficient β_τ for the horizon $\tau > 1$. With the estimation results in Table 5, Figure 9 plots β_τ as a function of the forecast horizon τ in the period from November 2008 to March 2013 (the dotted line) and after April 2013 (the solid line), respectively. When the horizon τ increases, the factor loadings on the slope and curvature become smaller and thus β_τ becomes smaller. As we have conjectured, β_τ becomes smaller after the introduction of QQE, which implies that the correlation between short-run and long-run expectations becomes smaller and the anchoring of inflation expectations becomes stronger.[12]

[11] Strictly speaking, they propose the several mathematical conditions for characterizing the degree of inflation expectations anchoring and discuss the relations between such conditions and the regression based on (12). See Kumar et al. (2015) for details.

[12] For robustness, we also estimate the version of the model that allows (i) the AR coefficients of the all factors to vary over the three groups of the periods, and (ii) the variance of the slope and curvature factors

5 Conclusion

This paper investigates whether a series of unconventional monetary policies conducted by the Bank of Japan in 2013 contributed to increasing long-run inflation expectations, which had been below 0 percent. Using a panel survey data of Japanese professional forecasters, we estimate the dynamic Nelson-Siegel model and inflation expectations curves over various forecast horizons.

We find that the introduction of Quantitative and Qualitative Monetary Easing (QQE) in April 2013, rather than raising the inflation target from 1 percent to 2 percent in January 2013, actually made a significant impact on the expectation formation process of professional forecasters in Japan. After the introduction of QQE, long-run inflation expectations increased to a maximum of 1.18 percent by the first half of 2014 but declined afterward. Our estimates suggest a high degree of intrinsic persistence of long-run expectations in Japan, in the sense that it takes time for long-run expectations to move back to the steady state when exogenous shocks occur. On the other hand, our estimates also provide additional information about the anchoring of inflation expectations. In particular, we find that the conditional volatility of long-run inflation expectations and the correlation between short-run and long-run expectations become smaller after the introduction of QQE. Overall, our result suggests that inflation expectations in Japan have "re-anchored" to the level around 1 percent since the introduction of QQE.

Our finding highlights three possible lessons for central banks, which may confront the challenge to "re-anchor" inflation expectations in the future without relying on the conventional tools. First, monetary policy can be effective in raising long-run inflation expectations, even though the short-term policy rate is constrained. Second, the announcement of a higher inflation target itself does not guarantee the re-anchoring of inflation expectations. Third,

to vary over the three groups of the periods. In the both modifications, we verify that the coefficient β_τ becomes smaller after the introduction of QQE.

central banks should pay careful attention to the dynamic properties of long-run inflation expectations and take quick policy actions in response to a sign of de-anchoring in the case of highly persistent inflation expectations.

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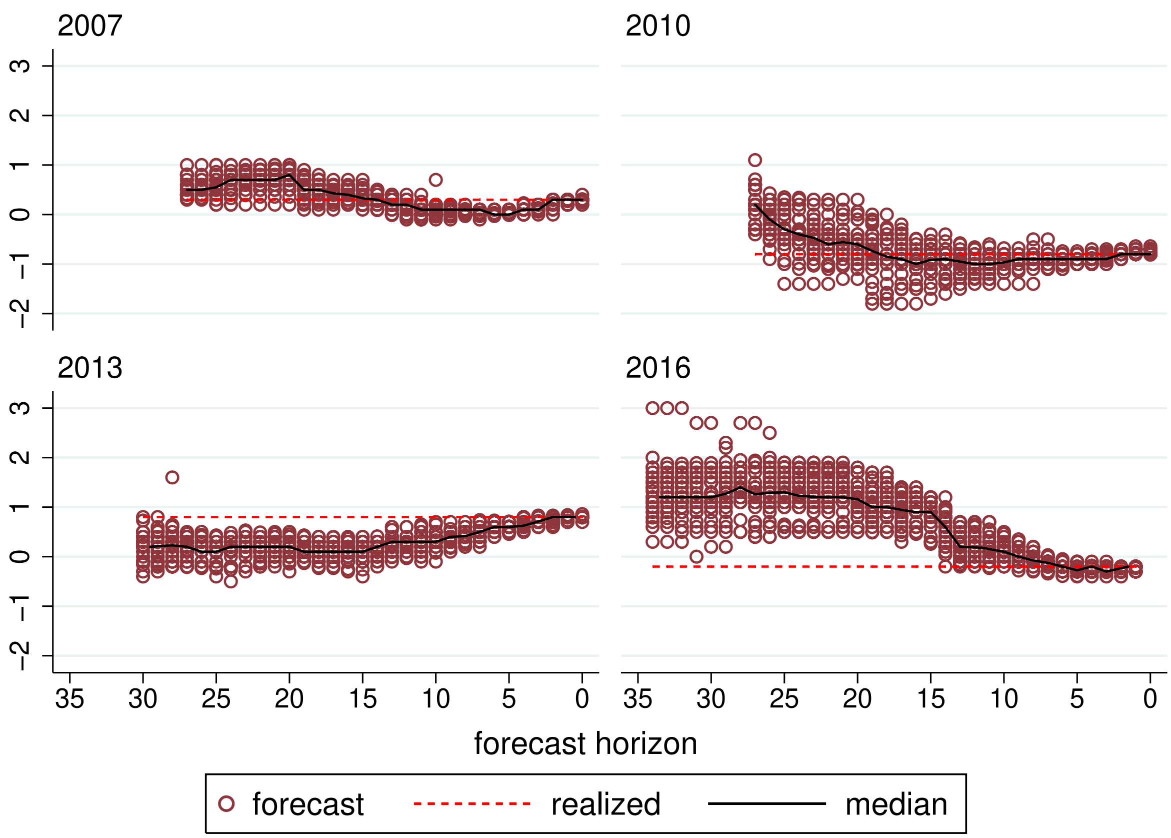
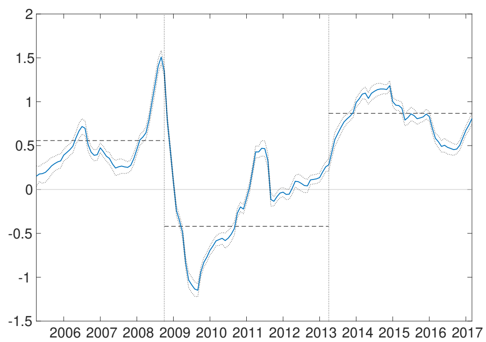
Figure 1: Individual Inflation Forecasts



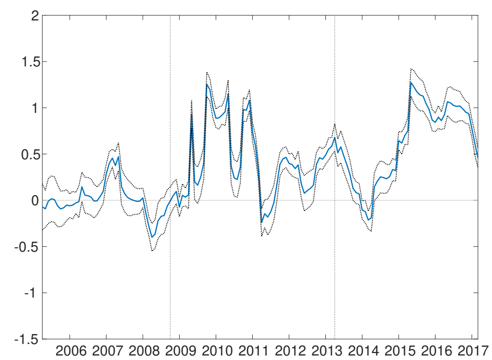
Notes: The figure plots the distribution of reported individual inflation forecasts (percentage) in the *ESP Forecast* for four selected target fiscal years, 2007, 2010, 2013, and 2016. In each graph, the horizontal axis represents the forecast horizons ($h = 1$ to 35). The solid line denotes the median of reported forecasts at each month and the dotted line denotes the realized value of annual inflation at each year.

Figure 2: Extracted Factors

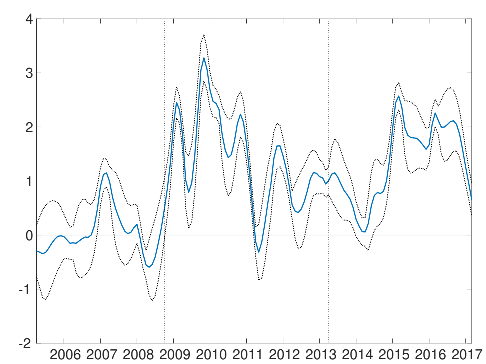
(a) Smoothed Level Factor



(b) Smoothed Slope Factor



(c) Smoothed Curvature Factor

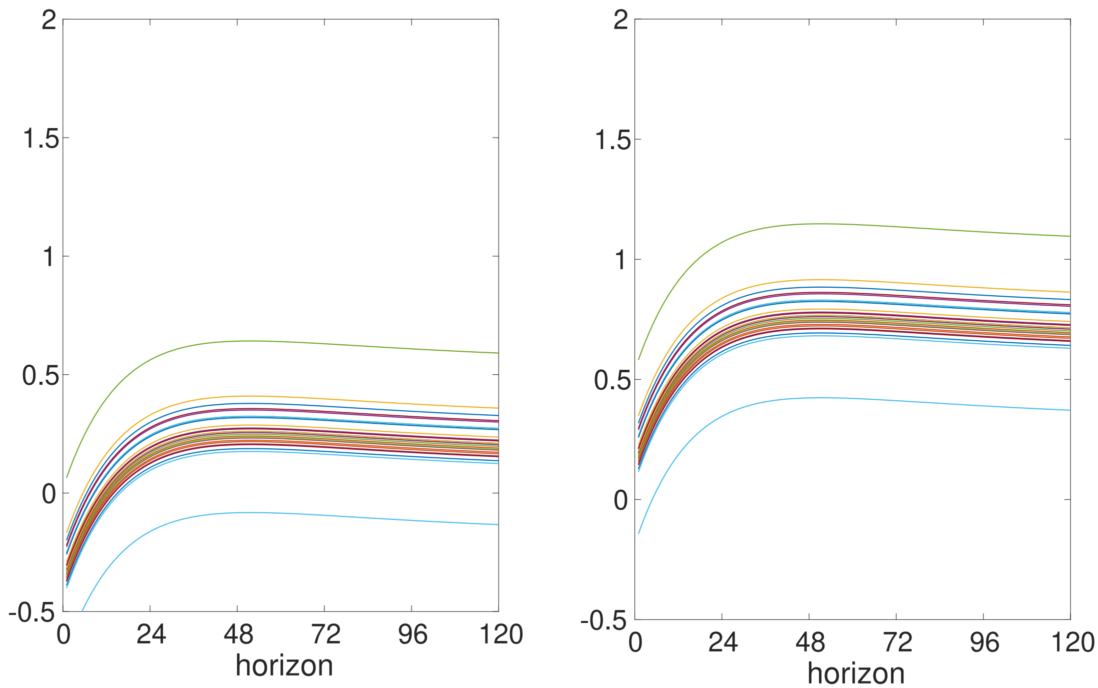


Notes : The solid lines denote the smoothed factors and the dotted lines denote their pointwise 95 percent confidence bands. The horizontal dashed lines in Panel (a) denote the mean of the level factor in corresponding periods. The two vertical lines denote November 2008 and April 2013, respectively.

Figure 3: Inflation Expectations Curve before and after QQE

(a) before QQE

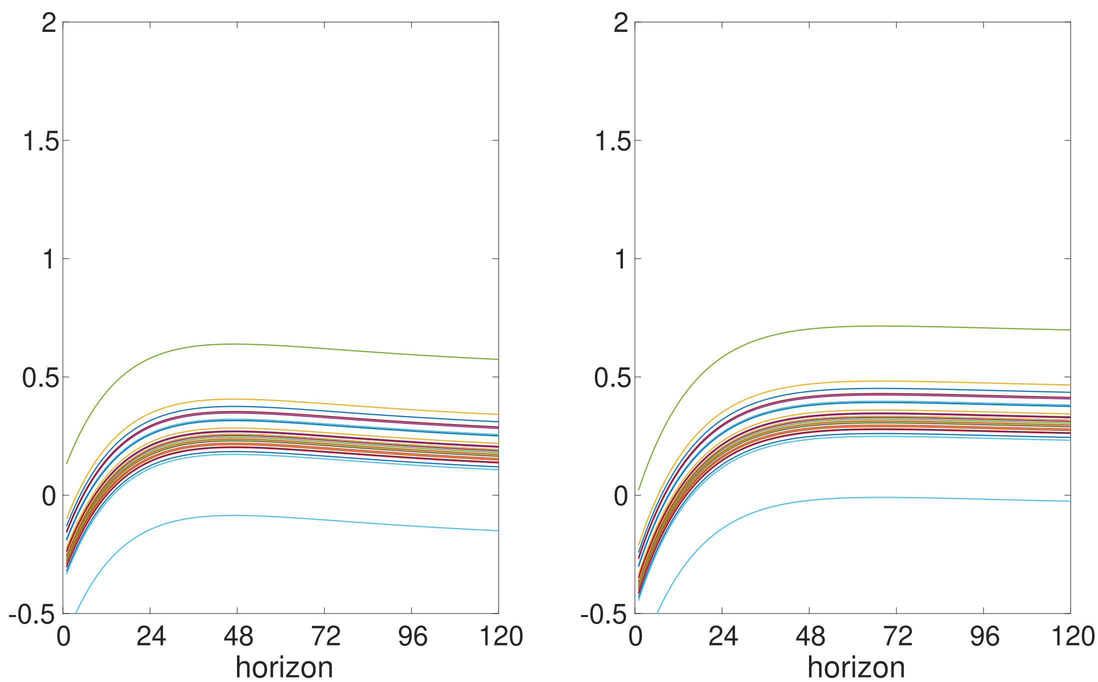
(b) after QQE



Notes : Each solid line denotes the inflation expectation held by each individual forecaster.

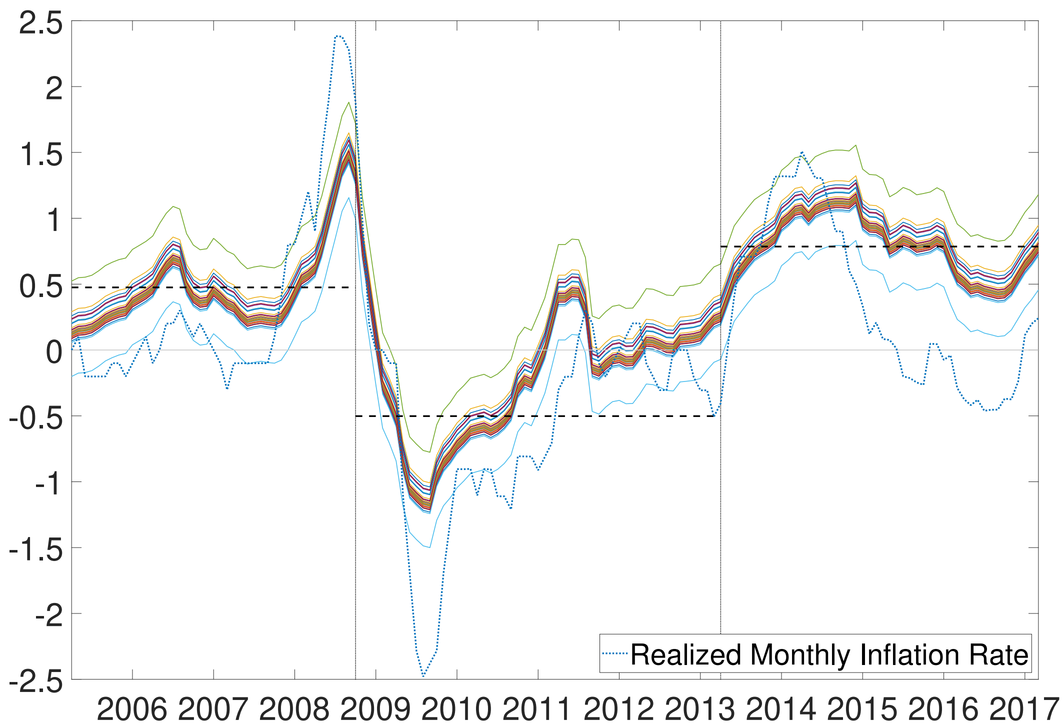
Figure 4: Inflation Expectations Curve before and after Raising the Inflation Target

(a) before raising the target (b) after raising the target



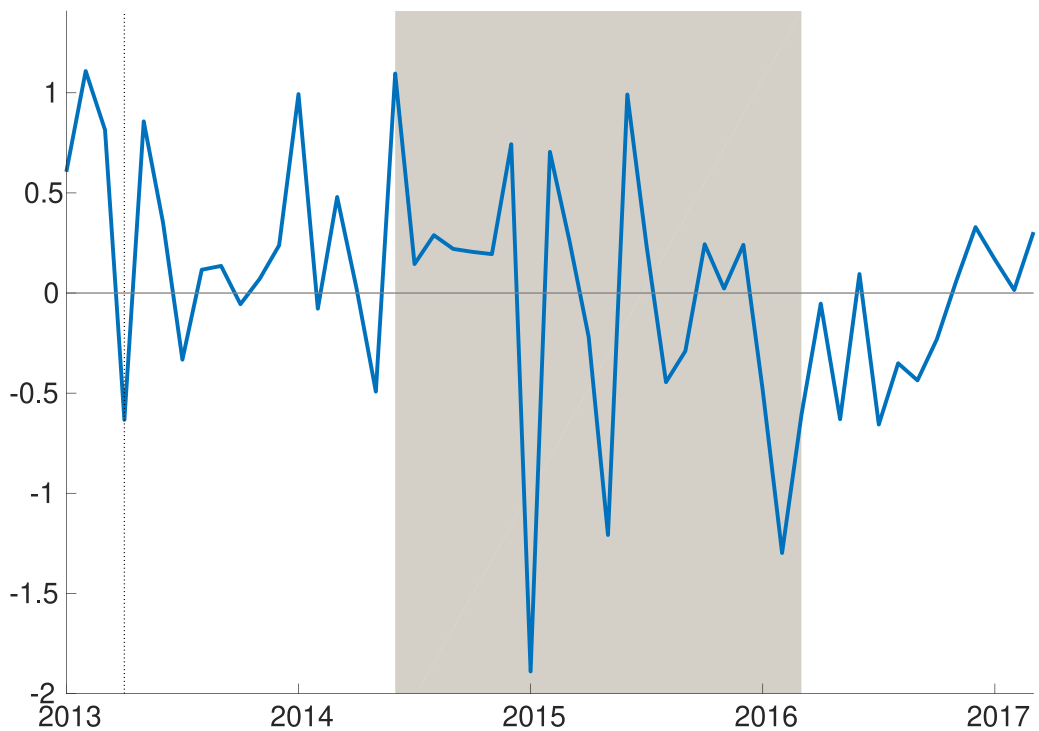
Notes : Each solid line denotes the inflation expectation held by each individual forecaster.

Figure 5: Long-run Inflation Expectations



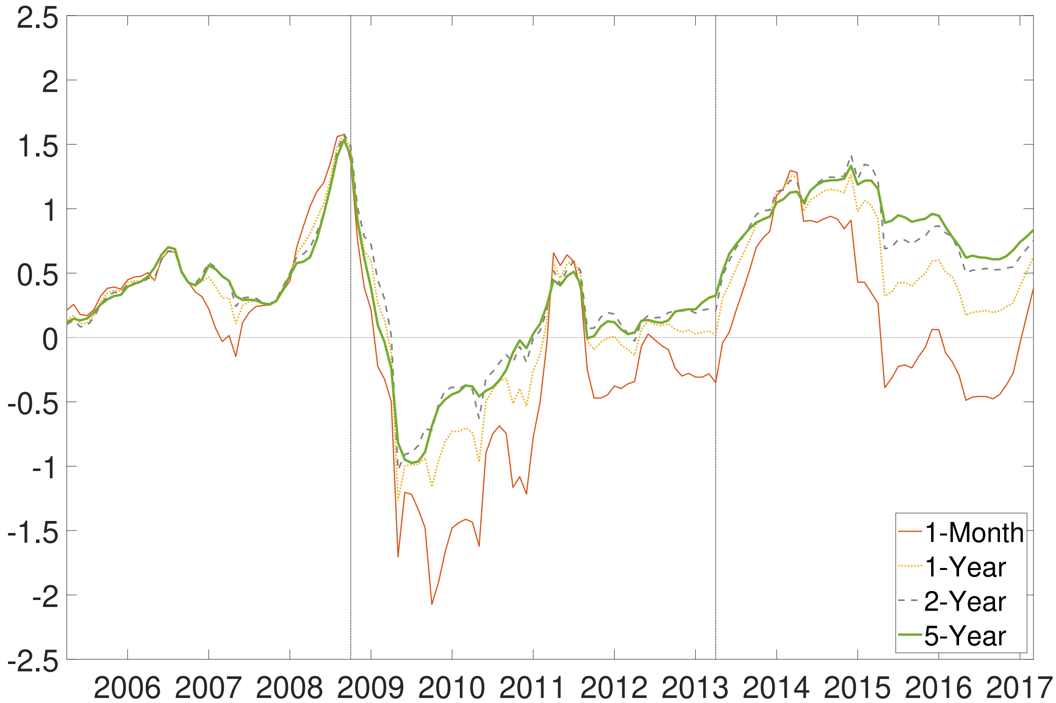
Notes : Each solid line denotes the inflation expectation held by each individual forecaster. The dotted line denotes the realized monthly year on year inflation rate (all items, less fresh foods). The horizontal dashed lines denote the cross-sectional mean of inflation expectations in corresponding periods. The two vertical lines denotes November 2008 and April 2013, respectively.

Figure 6: Extracted Shocks to the Level Factor



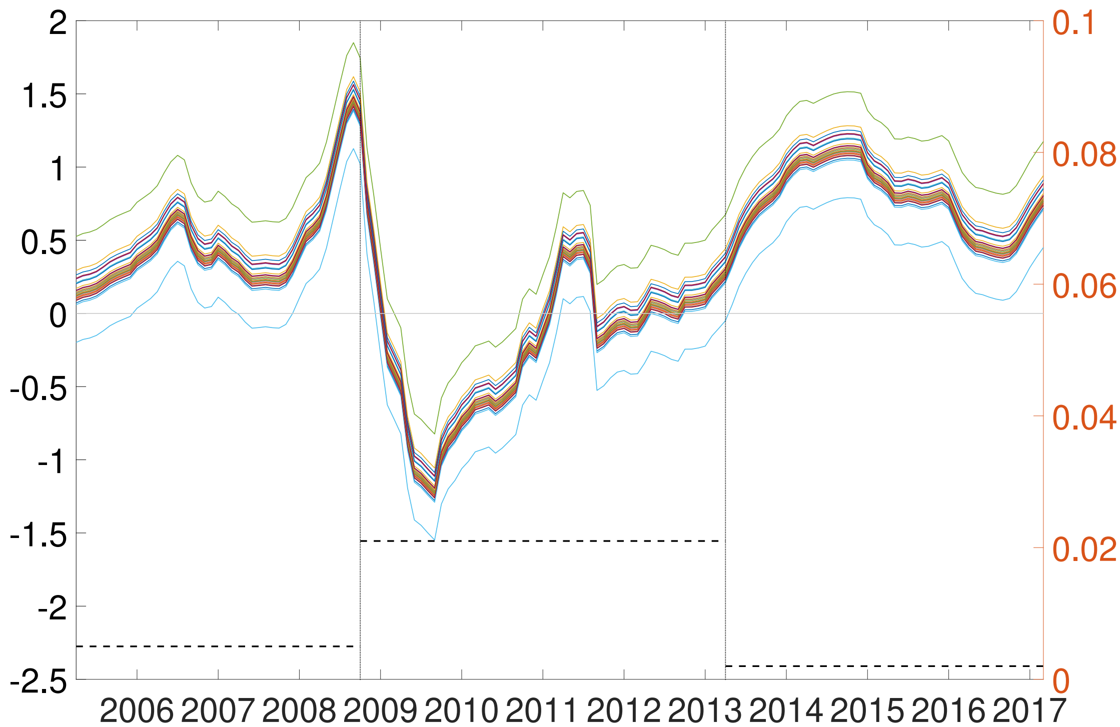
Notes : The solid line denotes the extracted exogenous shocks to the level factor. The vertical line denotes April 2013. The gray-shaded area shows the period of oil price declines.

Figure 7: Inflation Expectations for Selected Horizons



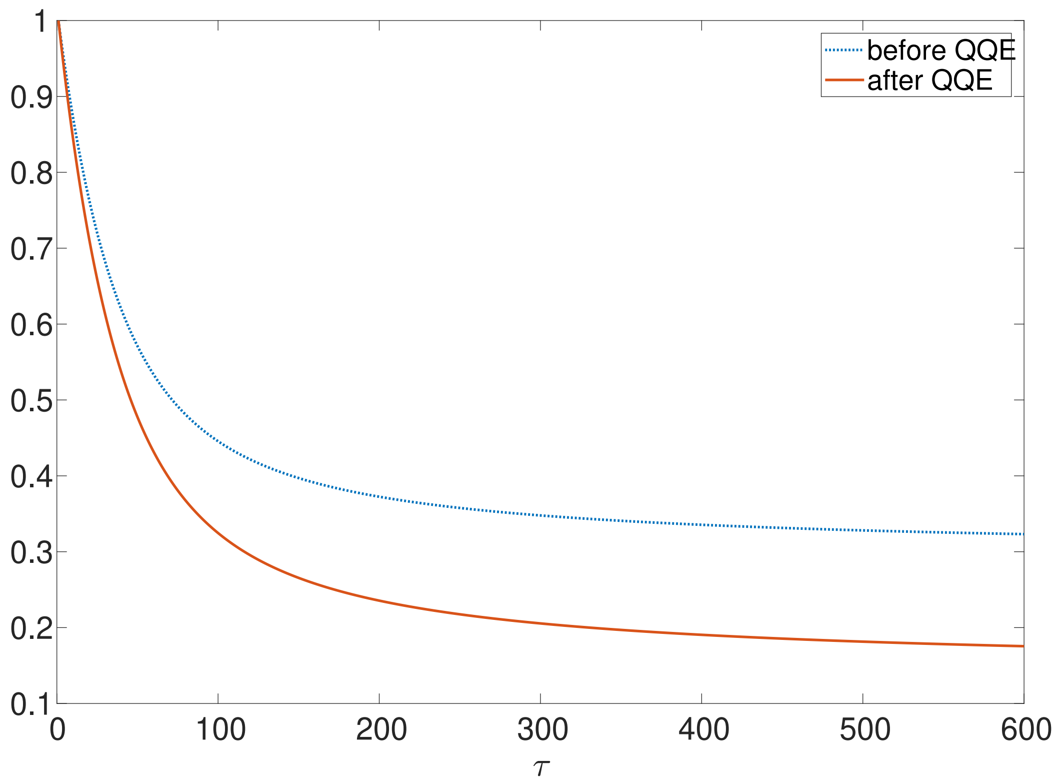
Notes : The two vertical lines denote November 2008 and April 2013, respectively.

Figure 8: Long-run Inflation Expectations in the Extended Model



Notes : Each solid line denotes the inflation expectation held by each individual forecaster (left axis). The horizontal dashed lines denote the conditional variance of the level factor in corresponding periods (right axis). The two vertical lines denote November 2008 and April 2013, respectively.

Figure 9: Correlation between Short-run and Long-run Inflation Expectations



Notes : The dotted and solid lines denote the correlation between $\bar{\pi}_t(\tau)$ and $\pi_{t+1|t}$ in the period before and after the introduction of QQE, respectively.