博士論文

Theoretical and Empirical Analyses of Unconventional Monetary Policy

（非伝統的金融政策の理論・実証分析）

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Chapter 1

Introduction

In recent years, Japan has experienced a number of dramatic changes in the monetary policy environment. In January 2013, the Bank of Japan (BOJ) introduced a formal inflation target of 2% specified in terms of year-on-year rate of change in the CPI inflation. A few months later, in April 2013, the BOJ announced a launch of a brand new monetary easing regime, quantitative and qualitative easing (QQE). After expanding QQE in October 2014, it adopted a negative interest rate policy in January 2016, which is followed by "QQE with Yield Curve Control" policy in September 2016. Under the QQE regime, the main operating target was shifted from overnight call rate to monetary base and the purchases of various assets including Japanese government bonds had been significantly increased. In fact, the BOJ succeded to accelerate the pace of increase in the monetary base until 2015, and its growth rate has still been stable at this time.

This dissertation analyzes the series of unconventional monetary policy in Japan from empirical and theoretical perspectives. The first two chapters empirically investigate the effect of recent monetary policy on expectation formation process of private agents by using Japanese forecasters' survey data. The results of these chapters imply some success of the BOJ's recent policy to increase the long-run and medium-run inflation expectations. However, at the same time, the results also suggest the possibility that the BOJ has faced some credibility problems in achieving its commitment and uncertainty about the transmission mechanism of its monetary policy. Based on this implication, the final chapter theoretically analyses the optimal policy when the central bank cannot commit to the future path of the economy and also faces the economic model uncertainty.

1.1 Outline

The remainder of this introduction start with a review of Japanese economy and BOJ's monetary policy conduct in recent years. It is intended to make it clear why and how variety of unconventional monetary policies have been considered and actually conducted in Japan. In the review, we present a detailed exposition of QQE policy, with especially focusing on the transmission mechanism the BOJ expected for the policy and its distinct features compared with the policy untill that time.

Chapter 2 evaluates empirically the impact of QQE on the long-run inflation expectations of private agents in Japan. To this purpose, we use "ESP Forecast", a panel data set of survey forecast in Japan conducted by the Japan Center for Economic Research. In the chapter, we propose a simple model-based approach to conduct the inference on long-run inflation expectations at the infinite horizon based only on short-run inflation forecasts available in our data. In particular, we estimate an autoregressive model with fixed effects to detect the possible shift of parameters in the model. In addition to this, we also consider the sticky information structure to incorporate the information friction in forming inflation expectations. Previous studies often indirectly measure the degree of information stickiness based on the correlation of ex-post average forecast errors and ex-ante average forecast revisions. Instead, we directly measure the frequency of information updating using the month-to-month revision by each agent. By estimating the several specifications, which include a smooth transition autoregressive model, we successfully capture both the changes of cross-sectional dispersion of private agents' long-run inflation expectations and the time-varying effect of QQE on them. Our result implies that the introduction of QQE in April 2013 actually gave the significant impact to the professional forecasters and succeeded to raise the long-run inflation expectations of them toward the target of 2%. In particular, the forecasters who had the long-run expected inflation around 0.5%, have changed their mind to trust the inflation in Japan to be converged in the level around 1%. When focusing on the temporary effect of QQE, the change can be seen more clearly that long-run inflation expectations increased on average from 0.41 percent to 1.61 percent. The result suggests that the aggressive monetary policies by the BOJ in recent years are at least partially successful for providing a good start point to escape from the deflationary regime and to transform the deflationary mind of the private agents in Japan. However, at the same time, it also implies that the effect is not sufficient to achieve the 2% inflation target in near future and furthermore, it has deteriorated in recent years. About the distribution of individual inflation expectations, we find some interesting facts. In the pre-QQE periods, cross-sectional dispersion of long-run inflation expectations is relatively large. In contrast, in the post-QQE periods, the estimated distribution of inflation expectations of forecasters have massed around the 1% point. The outcome suggets that the heterogeneity about the perspective for the future inflation path has shrined, or in other words, QQE succeeds to "anchor" the long-run inflation expectations of private agents, although the anchored level is significantly lower than the target 2%.

Chapter 3 investigates the impact of QQE by using the same data set, but from a different perspective. In the literature, a number of studies argue that an explicit inflation targeting regime can provide for less uncertainty about future inflation rates, which results in more stable medium-run or short-run inflation expectations of private agents. However, this argument is based on an implicit assumption that the central bank can achieve the explicit inflation target appropriately. The results of Chapter 2 imply that the anchored level of inflation expectations is significantly lower than the BOJ's explicit inflation target level 2%, and it is far from clear whether the argument above still holds true when the central bank faces a serious difficulty in anchoring the private agents' expectations to its inflation target level. To explore the recent conditions of medium and short-run inflation expectations formations by private agents in Japan, we estimate cross-sectional Phillips curves by using the forecaster-level data in "ESP Forecast". In particular, we consider the expectation-augmeted Phillips curve to decompose the changes of medium and short horizons inflation forecasts into the movement of three components: "anchor" of inflation expectations, the expectations for the future output gaps in Japan, and the expectations for the future realizations of supply shocks. By following the influence of these three components on the inflation forecasts in recent years, we investigate how the introduction of QQE affects the expectations formations by the private agents in Japan. The main findings in the chapter are three-fold. First, we find the way of forecasters' expectation formations is actually consistent with the expectation-augmented Phillips curve. The anchor of inflation expectations and the output gap forecasts have statistically significant effects on the inflation forecasts. About the expectations for supply shocks, the effect becomes significant in recent periods, especially after the introduction of QQE. Second, we capture the significant structural changes in the Phillips curve, occurs after the introduction of QQE. In particular, our estimation results indicate that the BOJ's QQE policy makes the inflation forecasts more sensitive to the GDP growth forecasts, or in other words, makes the slope of the Phillips curve steeper. The result here is in stark contrast to the literature which reports flattening Phillips curve in Japan by using pre-QQE periods data set. This chapter uses more recent data which includes the post-QQE period and update their results as suggesting the possibility of recovered relationship between output and inflation in Japan. Third, the estimated anchor of private inflation expectations, which has a feature of medium or short-run inflation expectations, changes dramatically in between pre and post QQE periods. Before the BOJ strongly committed to the achievement of 2% inflation target in April 2013, the estimated anchor of private inflation expectations was significantly negative. After the announcement, the new target and the policy thereafter increased the estimated anchor of inflation expectations to the significantly positive levels. On the other hand, the movement of anchor in the post-QQE periods differs between the medium and short-run expectations. In particular, the anchor of medium-run inflation expectations has been stable around the level of 0.5%. In contrast, that of short-run expectations starts to decline sharply at the end of 2015 and it now returns to the level before the introduction of QQE. In summary, our results in Chapter 3 show that the unconventional monetary policy series by the BOJ let medium and short-run inflation forecast more sensible to the output gap and supply shocks, which goes against "anchoring" argument of explicit inflation targeting.

Finally, Chapter 4 theoretically investigates the optimal monetary policy in an economy with an occasionally binding zero lower bound (ZLB) constraint on nominal interest rates, conducted by the central bank who faces model parameter uncertainty. How to conduct monetary policy in the face of uncertainty has always been an interest to both practitioners and academic researchers and a considerable amount of research has been devoted to this problem. However, since the previous research generally abstracts from the ZLB issue, the effect of model uncertainty on the central bank's monetary policy conduct in a liquidity trap situation has remained largely unclear. This chapter contributes to the model uncertainty literature by explicitly considering the possibility of nominal interest rate reaching ZLB. In this chapter, we focus on the argument of optimal discretionary policy with the ZLB constraint. In contrast to the commitment policy by which the central bank can credibly achieve higher expected inflation and a lower real interest rate even with the ZLB constraints, the discretionary policy is deeply involved with uncertainty. With an occasionally binding ZLB constraint, the possibility of future ZLB episodes lowers inflation expectations of private agents, creates a trade-off for discretionary central banks between inflation and output stabilization, even without explicit real shocks that generate the trade-off. This "deflationary bias" phenomena shows a great example that uncertainty about future causes unexpected result, especially when the central bank does not have a credible commitment device. We consider the central bank who faces uncertainty about the intertemporal elasticity of substitution. The value of parameter is significant for the central bank's decision in the face of a liquidity trap as it determines the size of output contraction and the effectiveness of the monetary policy in such a situation. In addition, there actually exists great uncertainty about the parameter in the literature and so it is reasonable to assume that the central bank also faces the same type of uncertainty. By using a Bayesian approach, we derive the optimal discretionary policy to deal with the uncertain parameter and the ZLB constraint at the same time. The main results in the chapter 3 are the following. With the parameter uncertainty, the zero interest rate policy is terminated earlier, in other words, becomes less aggressive compared to the case without uncertainty. In addition to this, the deflationary bias, which is the key phenomena of discretionary policy facing the ZLB constraints, caused by the absense of committing device of the central bank, deteriorates with parameter uncertainty. These results become stronger as uncertainty the central bank faces about the parameter increases. The key to understand the results here is the trade-off between the inflation rate and the output gap the central bank faces and the Brainard principle. The private agents' expectations that the central bank obey the Brainard principle, i.e., respond less aggressively to shocks, suppresses the downward pressure for the inflation expectations, which raises the actual inflation rate in the equilibrium.

1.2 History of Recent Monetary Policy in Japan

In April 2013, the Bank of Japan (BOJ) announced a launch of a new regime of monetary easing, Quantitative and Qualitative Easing (QQE). To make it clear how QQE is distinct compared to the monetary policy in Japan until that time and why we focus on it, we divide the unconventional policy series conducted by the BOJ into four regimes and explain each of them with a performance of Japanese economy in corresponding period: the Zero Interest Policy (ZIP, 1999–2000), the Quantitative Easing (QE, 2001–2006), Comprehensive Monetary Easing (CME, 2010–March 2013), QQE and its sequel policy (April 2014–).

Zero Interest Policy regime (1999–2000)

The history of unconventional monetary policy conduct in Japan started from financial crisis in 1990s, which was triggered by the collapse of the bubble in real estate and stock prices. Despite the earnest policy efforts such as the Japanese government's massive increase in government spending or the BOJ's several capital injection programs, Japanese economy went into a prolonged recession with negative output gap and mild deflation, which came to be reffered to "lost decade" in later years. All of the growth rate of the consumer price index (CPI), the CPI less fresh food (core CPI), and the CPI less food and energy (so-called core core CPI) shifted to a continuous modest decline phase from 1999 (Figure 1.1). The output gap, which is defined as the difference between gross domestic product (GDP) and potential GDP as a percentage of potential GDP, has suggested demand shortage over the same period (Figure 1.2). Such recession in Japan was basically due to weak domestic consumption and investment, while financial conditions in both inter-bank money market and corporate funding market were already accommodative enough (Figure 1.3).

Against the background, in February 1999, the BOJ introduced a Zero Interest Policy (ZIP), which lowered the uncollateralized overnight call rate (hereinafter, referred to as "the policy rate") to a level as low as possible. By providing short-term funds against pooled collateral such as Japanese Government Bonds (JGB), the BOJ guided the policy rate to the level below 0.15%. In addition to this, the then BOJ Governor Masaru Hayami declared that the BOJ will maintain the policy "until deflationary concerns are dispelled." In the sense that the central bank preliminarily expresses the condition of continuing the particular policy, it can be interpreted as the first "forward guidance" in the monetary policy history. However, at the same time, since the definition of "deflationary concerns" being unclear and the guidance itself was done in the informal form, the market participants in those days had diverging views about the exit timing of the ZIP regime.[1]

In August 2000, the BOJ claimed that "downward pressure on prices stemming from

[1] The statement was given at the press conference after the Monetary Policy Meeting in April 1999.

weak demand is markedly receding" and decided to terminate the ZIP, raising the policy rate to an average of around 0.25% (Figure 1.3). In those periods, even though some indicators such as industrial production or exports suggested modest recovery of the economy, the rate of change in the core CPI and output gap remained negative (Figure 1.1 and 1.2). While the BOJ repeatedly pointed out the risk of non-normal situation arising with the extremely low policy rate and was rushing toward normalization of its monetary policy, the situation was not so clear to convince the markets about the timing of exit. Indeed, the decision turned out to be reversed in February 2001, in response to the weak output gap and mild deflation thereafter (Figure 1.1 and 1.2).

Quantitative Easing (2001–2006)

Affected by the bursting of the IT bubble in the United states in 2000, output in Japan dropped sharply in early 2001 and the inflation rate remained in negative territory (Figure 1.1 and 1.2). In this environment, the BOJ again let the policy rate decline to 0.001% and adopted a new monetary easing framework called the Quantitative Easing (QE).[2]

In this regime, the main operating target for money policy was shifted from the policy rate to the current account balance at the BOJ. By providing short-term funds with maturities of 1 year or less, the BOJ raised the current account balance from 5 trillion yen to finally 30–35 trillion yen throughout the QE policy periods. At the same time, it provided forward guidance, which stated that the QE will "continue to be in place until the condition of the core CPI registers stably zero percent on a year-on-year

[2] About the ZIP and QE policy in Japan, see Bernanke [7], Kuttner and Posen [49], Svensson [85], Svensson [86], Okina [68], Mckinnon [55], [57], Oda and Okina [65], Fujiki et al. [25], Ueda [89], Ueda [90], Ugai [92] and Oda and Ueda [66].

increase". In contrast to the case under the ZIP regime, the exit condition of the policy was clarified in October 2003: (1) zero percent or above (the most recently published) core CPI holds for at least several months, (2) the projected core CPI is no lower than zero percent.

The economic conditions in Japan moderately improved throughout the QE periods. The output gap had entered positive territory at the end of 2005 at least based on the BOJ estimate (the estimate of the Cabinet Office suggested slightly negative gap, see Figure 1.2). The rate of change in the core CPI rose gradually toward 0% (Figure 1.1). One concern was that like the United States, there was a sign of flattering Phillips curve, which is the phenomenon of the rate of increase in the CPI becoming less sensitive to changes in the output gap. Indeed, compared to the relatively rapid recovery of output gap after 2004, the inflation rate seemed to slack around the level slightly below 0%.

Nevertheless, based on the nearly positive inflation from the end of 2005 until January 2006 and the expectation of further improvement in the output gap, the BOJ judged that the conditions in the commitment above had been fulfilled and decided to exit the QE regime. On March 2006, the BOJ announced that the uncollateralized overnight call rate will be re-introduced as an operating target for money market operations and its targt will be set at effectively 0% for the time being. At the same time, it adopted a new framework for the conduct of monetary policy, so-called "the understanding of medium to long-term price stability" (hereinafter, referred to as "the understanding") . In this framework, the level of inflation rate recognized as price stability by each Policy Board member of the BOJ was reported in each year. The indicator was meant to tell the objective of monetary policy and be a guide to the private agents in Japan about the future path of the policy rate, but on the other hand, the BOJ repeatedly expressed that it was not an inflation target. The understanding was initially set between 0 and 2% with the median of 1%.

Comprehensive Monetary Easing regime (2010–March 2013)

The collapse of subprime mortgage market in the United States and the crisis in the banking system of the European countries developed into the global financial crisis in 2008. Thanks to a series of accommodative monetary policy and active fiscal package adopted in major countries, global economies showed a signs of a moderate recovery from the second half of 2009. However, the pace of global economic growth began to slow after mid-2010, partly because of the sovereign debt problem in some european countries. Japan was no exception, suffered from severe slowdown of growth in exports and production by continuous appreciation of yen.

In the sense that the policy rate in Japan had already been in very low level at that time, the BOJ virtually adopted the zero interest rate policy again (Figure 1.3). As additional monetary easing tools, it introduced the Comprehensive Monetary Easing (CME) policy in October 2010.[3] The main monetary operation in the CME regime was "Asset Purchase Program", which purchased JGB as well as variety of risk assets such as treasury discount bills, commercial paper, corporate bonds, exchange-traded funds, and Japan real estate investment trusts. While the policy rate had already reached nearly the zero lower bound, relatively longer-term interest rates in Japan still remained in positive territory (Figure 1.3). The program was meant to exert downward pressure on them by mainly purchasing JGB with remaining maturity 1–2 years (extended to

[3] About CME policy in Japan, see Lam [50], Ueda [91], Kimura and Nakajima [43], Filardo and Hofmann [23] and Shirai [79].

1–3 years in April 2012) and create a more accommodative monetary environment by reducing the funding cost of investment. The total amount of the Asset Purchase Program was increased in a step-by-step manner from initially 35 trillion yen in 2010 to 111 trillion yen in 2013 (sum of newly purchased assets and fixed-rate Funds supplying operations). In January 2013, the BOJ decided to start an open-ended asset purchasing method from early 2014, which would purchase financial assets of about 13 trillion yen in each month without setting any termination date.

In addition to the actual operations explained above, the BOJ also provided the forward guidance statement that it will "maintain the virtually zero interest rate policy until price stability is in sight on the basis of the understanding of medium to long term price stability, on the condition that no serious risk factors were identified". Further, in February 2012, it declared that the BOJ "will continue pursuing the powerful easing until it judges that the 1 percent goal is in sight".

Despite these relatively aggressive monetary easing at least compared to the past unconventional policy conducted in Japan, the CME framework was exposed to criticism from both domestically and abroad. One of the main criticism was that the BOJ's policy lacked credibility. Since the introduction of the CME in October 2010, the size of the Asset Purchase Program has been expanded nine times and the total size was substantially increased. On the other hand, the scale of each expansion was in the range of 5–10 trillion and such gradual adjustment might have given that the market participants the impression that the BOJ's policy lacked boldness. In addition, it was pointed out that the BOJ's communication strategy was not so effective. For example, the Bank itself repeatedly expressed the negative view about the inflation targeting framework, stressed the risk of it and because of such attitude, the word "goal" in the forward guidance statement gave ambiguous impressions and caused doubts about the BOJ's intention to overcome the prolonged deflation.

Given the mild deflation and declining output gap since the second half of 2012 (Figure 1.1 and 1.2), the BOJ finally shifted from a price stability "goal" to a price stability "target" as 2% of the year-on-year change in the CPI. Since the BOJ had left the ambiguity whether its forward guidance included the price "target" by this time, the adoption of explicit 2% price stability target was a dramatic change in the history of monetary policy conduct in Japan. However, at the same time, the BOJ at this time announce nothing about additional policy tools, so some doubts were expressed by the public and markets that the 2% target was really achievable only with the existing policy framework.

Quantitative and Qualitative Easing regime (April 2013–)

In April 2013, the BOJ announced the introduction of a new monetary policy framework, the Quantitative and Qualitative Easing (QQE). It was adopted to achieve the price stability target of 2% at the earliest possible time, with a time horizon of about 2 years. In this framework, the main operating target for money market operations was shifted from the policy rate to the monetary base. The BOJ promised to increase the monetary base at an annual pace of about 60-70 trillion yen, which meaned to double it by the end of 2014. For the purpose, the BOJ started to purchase massive amounts of JGB and the various risky assets. It announced that the purchase of JGBs would go at the pace that their amount outstanding will increase at an annual pace of about 50 trillion yen. In addition to such "quantitative" accumulations, the Bank also tried to utilize "qualitative" device, extend the average remaining maturity of its bond purchases from about three years for that time to seven years by preferentially purchasing long-term bonds with maturities up to 40 years. Further, with the introduction of QQE, the BOJ stated the forward guidance about the time span of monetary accommodation. The guidance can be decomposed into two parts, such as

1. The BOJ will achieve the price stability target of 2 percent at the earliest possible time, with a time horizon of about two years,

2. The BOJ will continue with QQE, aiming to achieve the price stability target of 2 percent, as long as it is necessary for maintaining that target in a stable manner.

These two statements are apparently clearer than those of the past forward guidance expressed by the BOJ and intended to reinforce the credibility of the BOJ's commitment to achieving the inflation target. Corresponding these two descriptions, the BOJ Governor Haruhiko Kuroda stressed that QQE included all the necessary measures to achieve the 2% target within 2 years but at the same time, admitted that there is uncertainty about working of policy or responsiveness of people's expectations to it, so the Bank would continue with monetary easing as long as it was necessary to achieve the 2% target in a stable manner so that everyone was convinced that sufficient monetary easing would be implemented.

What is the striking difference between the QQE regime and the other past series of unconventional policy? The most distinct and important feature of QQE is its emphasis on the inflation expectations as the transmission channel for achieving the 2% target. As the BOJ repeatedly explain after the introduction of QQE, the intended policy scenario is the following;

1. Massive increase of the monetary base, the purchase of various risky assets and strong commitment about future path of the economy makes households and firms believe inflation to rise in the long-run.

2. As the Fisher equation suggests, the real rate can be decomposed

$$r_t = i_t - E_t\pi_{t+1},$$

   which subtracts the expected inflation rates ($E_t\pi_{t+1}$) of the private agents from the nominal interest rates (i_t) basically observed in financial markets. By sustaining the virtually zero interest rate and rising inflation expectations, the policy can lower the real rate.

3. The lowered real interest rate will stimulate the households' consumption behavior and the firms' pricing behavior, which positively affect the current levels of nominal price levels such as sale prices and wages.

To execute the scenario above, the most important mission for the QQE is to raise the inflation expectations. When considering the impact of policy on the inflation expectations, attention needs to be paid to which measure of expectations to focus on and what time horizon to use. According to the context, the word "inflation expectations" can indicate both short-run expectations (formed within less than one or two years) and long-run expectations (formed with a time horizon of over five or more year). Almost all Inflation-targeting central banks including the BOJ choose the latter as a target. One reason is that the long-run inflation expectations can be a good indicator of long-term real interest rates, which strongly affect the business investment by firms or residential investment and consumption of durable goods by households. In the sense that the BOJ's policy scenario includes the stimulation of these behaviors as the transmission channel, it can be said that the target of QQE is the long-run inflation expectations. For this reason, Chapter 2 in the dissertation focuses on the analysis about the impact of QQE on the long-run inflation expectations of private agents in Japan.

On the other hand, to accomplish the "stable" 2% inflation as the BOJ declared in the guidance, not only to raise the inflation expectations, but also to firmly "anchor" the expectations at the target level 2% is needed. If the inflation expectations are "anchored" at some level, they become insensitive to the exogenous shock. Since the relatively short-run inflation expectations are more likely than long-run expectations to be affected by the factors beyond monetary policy, for example the supply shocks such as the transitory changes of crude oil prices, to check the movement of such short to medium inflation expectations is important. This is one of the motivations for Chapter 3.

About one and a half year after the launch of QQE, in October 2014, the BOJ decided to expand it to deal with a risk of sharp decline in long-term inflation expectations, which was mainly due to weaker demand with a consumption tax hike and an oil price drop from mid-2014. The annual pace of increase in the monetary base and the amount outstanding of the assets holdings was accelerated and the average remaining maturity target of JGB purchases was extended to about 7-10 years. Furthermore, in January 2016, the BOJ started a negative interest rate policy, which adopted a negative interest rate on part of excess reserves. Even under the new regime, the main operation of the Bank was not changed, rather, strengthened. The average remaining maturity of JGB purchase was further extended to 7-12 years while the pace of increase in the monetary base was set to remain as the same. Soon after expanding ETF purchase at the July 2016, the BOJ introduced QQE with Yield Curve Control (QQE-YCC) policy in September 2016. Under the new regime, various new frameworks have been implemented until now, such as yield curve control, which tries to control short-term and long-term interest rates at the same time, and an inflation-overshooting commitment, which commits to continue the monetary base expansion until the inflation rate exceeds the price stability target of 2% and stays above the target in a stable manner.

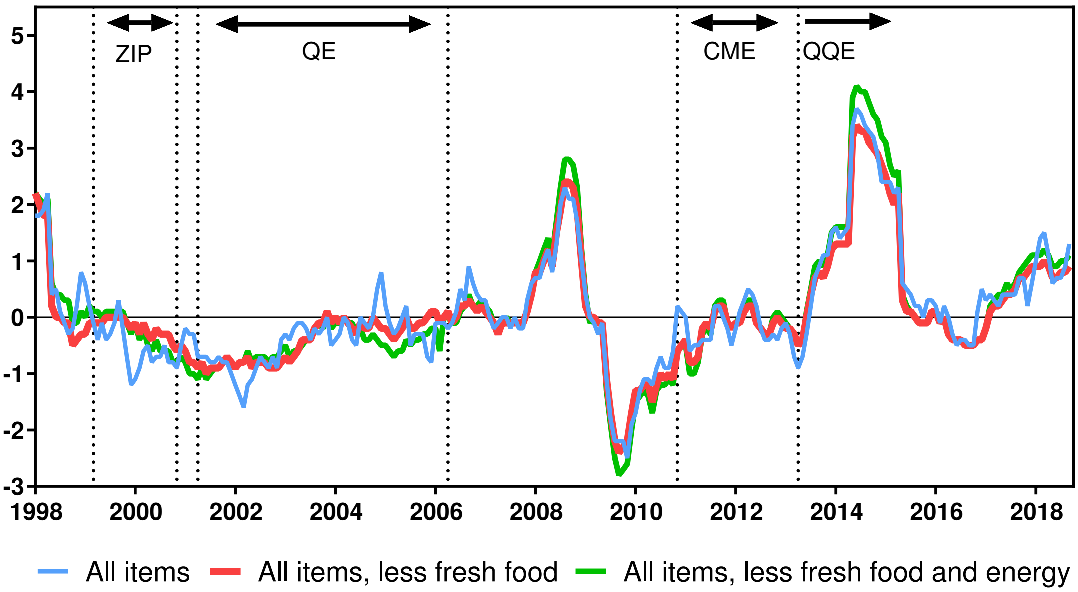

Fig. 1.1: Annual Percentage Change in CPI in Japan

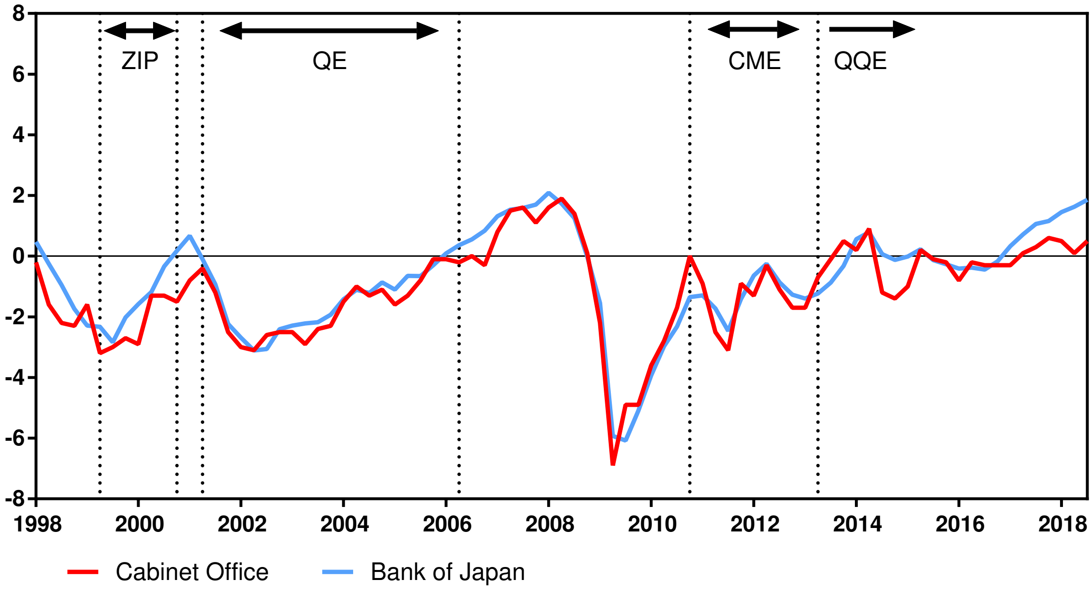

Fig. 1.2: Output Gap in Japan

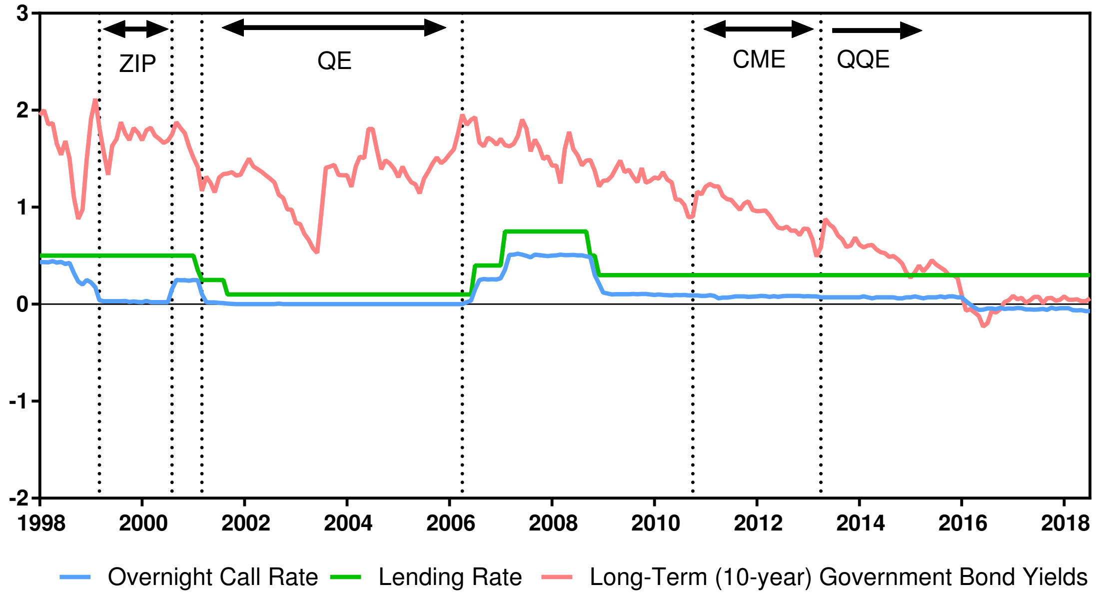

Fig. 1.3: Interest rate in Japan

Chapter 2

The Effects of QQE on Long-run Inflation Expectations in Japan

2.1 Introduction

Even though the form of implementation has been changed during several rounds of monetary easing in the past several years, the central objective of the policy clearly remains unchanged: raise inflation expectations of firms and households, stimulate their desire for spending and investment, and finally, lifting the Japanese economy out of chronic deflation, which has lasted for nearly 15 years. The key factor for achieving this goal is, as the BOJ repeatedly emphasized, the management of inflation expectations. For example, the BOJ Governor Haruhiko Kuroda states that raising inflation expectations is "both an objective of QQE and, at the same time, the key to implementing the QQE transmission mechanism to overcome deflation" in Kuroda [47]. There is a growing consensus among both central bankers and academics that "well-anchored" inflation expectations of private agents are quite important for monetary policy, especially under the situation where the nominal rate is stuck at zero and the central bank has to depend on unconventional tools to recover the economy. How strongly households and firms realize that the policy regime critically changed and in consequence and believe that the inflation rate will converge toward the target in the long run can be seen a simple performance major for the recent unconventional monetary policy.

In this chapter, we use *ESP Forecast*, a panel data set of survey forecasts, to investigate how the introduction of QQE changes the inflation expectations of private agents in Japan. There are two distinct features in our analysis. First, we propose a simple model-based approach to conduct the inference on long-run inflation expectations at the infinite horizon based only on short-run inflation forecasts available in our data. In particular, we estimate an autoregressive (AR) model with fixed effects to detect the possible shift of parameters in the model. Second, we consider the sticky information structure of Mankiw and Reis [52] to incorporate the information friction in forming inflation expectations. Previous studies often indirectly measure the degree of information stickiness based on the correlation of ex-post average forecast errors and ex-ante average forecast revisions. Instead, we directly measure the frequency of information updating using the month-to-month revision by each agent.

By using our simple but flexible model, we succeed to estimate the cross-sectional distribution of individual inflation expectations. At the same time, by introducing a smooth transition factor into the benchmark model, we also capture the time-varying effect of QQE on the long-run inflation expectaions.

In summary, our estimation result implies that the introduction of QQE in April 2013 actually gave the significant impact to the professional forecasters and succeded to raise the long-run inflation expectations of them toward the target of 2%. In particular, the forecasters who had the long-run expected inflation around 0.5%, have changed their mind to trust the inflation in Japan to be converged in the level around 1%. When focusing on the temporary effect of QQE, the change can be seen more clealy that long-run inflation expectations increased on average from 0.41 percent to 1.61 percent. Thus, our results suggest that the aggressive monetary policies in recent years are at least partially successful for providing a good startpoint to escape from the deflationary regime and to transform the deflationary mind of the private agents in Japan. However, at the same time, our empirical results also suggest that the effect is not sufficient to achieve the 2% inflation target in near future and furthermore, it has deteriorated in recent years. In particular,the average value of estimated long-run inflation expectations, which increases from 0.425% to 1.467% soon after the introduction of QQE, decreases to 1.3% after January 2016. Of course we can not do the overall assessment of the recent policy only from our analysis, the result shows the possibility of challenging environments for the Bank of Japan that achieving the original commitment of the 2% stable inflation.

The chapter proceeds as follows: Section 2 provides an overview of the related literature. Section 3 briefly reviews the monetary policy history leading to the introduction of QQE in Japan. Section 4 describes the data we use in the analysis and outlines the empirical method, reports the results. Finally, Section 5 concludes.

2.2 Literature Review

Recently, many researchers have tried to examine the effect of unconventional monetary policy by using several different methods and data set. One approach is, which is actually adopted in this chapter, is to use the survey data of economic forecasts. Using the survey data of the household inflation expectations, Nishiguchi et al. [64] reports that after the introduction of QQE, more households have forecasted price increases than price declines and the skew of their expectations distribution has shifted to the inflationary side. Diamond et al. [18] investigate the relationship between the households' inflation experience and inflation expectations by using micro-level datasets of the same 13000 households in Japan. Kamada et al. [40] adopt a parametric model with a Normal inverse Gaussian distribution to the same data as Nishiguchi et al. [64] and conclude that QQE actually strengthened the anchor of long-term inflation expectations. On the contrary, Nakazono [61] argues that effects of the recent monetary policy may be not enough to change the private sector's perception about a policy stance, based on the data of various surveys for households, firms, professionals and market participants. His analysis is partly based on *ESP forecast data*, which we also use in the present chapter. Marked difference between Nakazono [61] and our approach is that we use micro-data, which allows us to explicitly deal with the heterogeneity between the forecasters and to break down the effect of recent monetary policy into common and individual-specific parts. Hattori and Yetman [33] adopts the model based on decay functions to forecaster-level data in Japan and find that the degree to which implicit inflation anchors pin down inflation expectations at longer horizons has increased in recent years. However, they also find that it may be considerably lower than Yetman [95] found by applying the same method for Canada or the United States data.

Another popular approach is to use Vector Auto-Regressive (VAR) model, interpret the unconventional monetary policy as a shock to the monetary instrument and try to identify the effect of such shock on the macroeconomic variables. Studies employing VAR approach include Kimura et al. [42], Fujiwara [26], Honda and Tachibana [37], Harada and Masujima [32], Nakajima et al. [60], Schenkelberg and Watzka [77], Hayashi and Koeda [36], Miyao and Okimoto [59] and Koeda [45].

As the main tool of unconventinal monetary policy is large-scale asset purchases, there exists many studies which use the financial market data such as risk or term premium of bond and the other risky assets. Studies using financial data include Kimura and Small [44], Ueda [91], Shibamoto and Tachibana [78], Fukuda [28] and Nakazono and Ikeda [62].

In another strand of research, the inflation environment in Japan has investigated by directly estimating the trend inflation with time-series data. For example, Kaihatsu and Nakajima [39] report that Japanese trend inflation had stayed at around zero percent since 1990s, but the introduction of the inflation target and QQE succeeded at changing the situation and shifting the trend away from zero. Okimoto [67] follows Kaihatsu and Nakajima [39] by using the hybrid Phillips curve model with regime switching and obtains a similar result, but also points out that the effect of monetary policy might not be enough to achieve the 2% inflation target for now and declines in oil and stock prices may pull back Japan to the deflationary regime, again.

The main part of our analysis is also related to the relationship between short-term and long-term expectations. Hattori and Yetman [33] adopt the model based on the cumulative density function of the Weibull distribution, which is proposed by Mehrotra and Yetman [56], to the data from Consensus Economics. They report that the estimated long-run expectations have rised in recent years, however, the dispersion or heterogeneity of the anchor across forecasters have also increased.

Our research also builds on the information rigidities literature. By adopting the sticky and noisy information frameworks proposed by Woodford [93], Mankiw and Reis [52] and Sims [80] to the survey data, Coibion and Gorodnichenko [12] and Coibion and Gorodnichenko [13] show that the formation of expectations by professional forecasters and other agents is consistent with the presence of information rigidities. To capture the behavior of the forecasters who infrequently update their information sets and forecasts, we introduce the sticky inforamtion framework into the basic model. Thanks to the structure of our model that receiving information is directly connected to revising the forecast, we can clearly identify when is the timing that the forecaster gives up acquiring new information and when is not.

2.3 Empirical Analysis

2.3.1 Data

ESP Forecast, a monthly survey on the macroeconomic forecasts, has been conducted by the Japan Center for Economic Research. Each month, about 40 professional forecasters are asked to provide their personal forecasts for macroeconomic and financial variables mainly on Japan over the current and the next fiscal year (from April to March of the following calendar year). The result including the average of the forecasts is published about a week after the close of the survey. The survey formally started in May 2004 with 38 participants, following a few dropouts and new entries, keeps almost the same number of respondents until now.

In our analysis, we use the forecasts of year-on-year changes in the consumer price index (all items, less fresh foods) for the current and the next fiscal years at the time of each monthly survey from April 2005 to December 2016. To break down the effect of recent monetary policy on inflation expectations into common and individual-specific parts, we use the individual non-aggregate data. In the panel data, a forecaster id is uniquely assigned to each forecaster, so we can follow the same forecasters in long enough periods. We pick up 29 forecasters who join the survey every month without dropping out from April 2005 to March 2017. Figure 2.1 shows the distribution of individual inflation forecasts for selected four target fiscal years, 2007, 2010, 2013 and 2016. The horizontal axes denote 28 minus the forecast horizon, $28 - h$, where 28 is the longest forecast horizon available.[1] In the figure, dots represent the individual inflation forecasts made by 29 forecasters after removal of non-response and attrition in the sample period. Dashed line and solid line represent realized values and median forecasts, respectively.

It is important to note that *ESP Forecast* collects "fixed-event" type of forecasts. In the fixed-event forecast data, the forecast event is kept fixed throughout, while the forecasting horizon shrinks as the forecast origin approaches the target event. As a result, forecast dispersion clearly decreases as the forecast horizon decreases in the figure. The figure shows that more disagreements can be observed in 2010 and 2016 compared to those in 2007 and 2013. Furthermore, downward bias is present in 2013 while upward bias is present in 2016.

In order to roughly see whether the recent movement of montary policy in Japan actually brings some changes to the forecasts, we conduct structural break tests using the univariate series of aggregated inflation forecasts. The $\sup F$ type test statistic is 39.53 with a trimming fraction of 0.15. For the double maximum statistics of Bai and Perron (1998) allowing for up to 5 breaks, $\mathrm{UD}_{\max} = 108.20$ and $\mathrm{WD}_{\max} = 147.94$ for the same trimming. All the statistics are above the corresponding critical values at the 1% significance level and the null hypothesis of no structural change is significantly rejected. Furthermore, the break date is estimated at April 2013, which matches the timing when the QQE policy was introduced. We also do the common break estimation following Bai [4] for the panel data and verify that the break is also estimated as April 2013.

[1] When the target fiscal year is 2006, the forecasts of $h = 28$ are made at January 2005 and the forecasts of $h = 1$ are made at April 2007, for example.

It is reasonable, therefore, to expect that the adoption of inflation targeting and QQE have had some impacts on the formation of inflation expectations by the professional forecasters.

2.3.2 A model of inflation forecasts

We denote the annual log inflation rate of a fiscal year by Π_t and the monthly log inflation rate at the annual rate by π_t. The forecast target in the survey can then be decomposed into 12 monthly inflation rates as

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

where T is the last month in the fiscal year of interest. We assume that each individual i constructs a forecast $\Pi^{i,AR}_{T|t}$ at period t in two steps.

STEP 1: Compute the monthly inflation forecast based on the AR model at horizons 1 to $T-t$.

$$\pi^{i,AR}_{t+1|t},\ \pi^{i,AR}_{t+2|t},\ \cdots,\ \pi^{i,AR}_{T|t}$$

STEP 2: Compute the annual inflation forecast by averaging 12 monthly inflation forecasts obtained in Step 1.

$$\Pi^{i,AR}_{T|t} = \frac{\pi^{i,AR}_{T-11|t} + \cdots + \pi^{i,AR}_{T|t}}{12}$$

In Step 1, we allow the long-run inflation expectations to differ across agents. For example, a 1-period ahead forecast can be computed by the panel AR model of order p

with the individual-specific term as

$$\pi^{i,AR}_{t+1|t} = (1-\beta)\Pi^*_i + \phi_1\pi_t + \phi_2\pi_{t-1} + \cdots + \phi_p\pi_{t-p} \tag{2.1}$$

where Π^*_i denotes the individual long-run expectation of agent i and $\beta = \sum_{j=1}^{p}\phi_j$ is the sum of AR coefficients. In Step 2, agents use all 12 monthly forecasts if the forecast horizon is larger than 12 months. For the current fiscal year forecasts with the forecast horizon below 12 months, we simply assume that the agent reports the weighted sum of the realized monthly inflation rates and the AR forecasts from the next month to the final month of the fiscal year.

Our interest is to examine whether the introduction of QQE contributed to changing the long-run inflation expectations, Π^*_i, on average (analogous to the average treatment effect). To this end, we replace Π^*_i in (2.1) by $\Pi^*_i + \alpha QQE_t$ where QQE_t is an indicator of the QQE period which takes value 1 if t corresponds to the month of April 2013 or after and 0 otherwise. Note that in this benchmark case, the impact of QQE represented by the parameter α, as well as AR coefficients, is assumed to be common across agents. However, we later relax this assumption and consider other specifications as well.

We also incorporate the sticky information structure. By construction of the AR forecast formation, agents should always revise their annual inflation forecasts of the target fiscal year as long as they update the information every month. If agents do not update the information in a particular month, the AR forecast rule implies that agents should report exactly the same forecast value as the previous month. Therefore, under the AR forecast assumption, we can directly observe the frequency of information updates in a standard sticky information model using the average fraction of the revision from month to month.

Let $\Pi_{T|t}^{i,ESP}$ be the reported value of annual inflation forecast of the fiscal year ending at T made at the period t by the agent i in the *ESP Forecast*. By combining the AR forecast and sticky information structure, we can estimate α and other parameters using the regression model of the form

$$\Pi_{T|t}^{i,ESP} = (1 - D_{it})(\Pi_{T|t}^{i,AR} + \varepsilon_{T|t}^{i}) + D_{it}\Pi_{T|t-1}^{i,ESP} \tag{2.2}$$

where D_{it} is the sticky information dummy variable which takes the value 1 if $\Pi_{T|t}^{i,ESP} = \Pi_{T|t-1}^{i,ESP}$ and 0 otherwise. The error term, $\varepsilon_{T|t}^{i}$, captures the deviation of the reported forecast from the theoretical AR forecast, provided that a forecast revision was made from the previous month. Because the weighted sum of AR forecasts with different horizons are nonlinear functions of AR parameters, we employ the generalized method of moments (GMM) estimator with lagged monthly inflation rates used as instruments. The lag order p in (2.1) is selected by the model selection criteria for GMM estimation proposed by Andrews (1999).

Finally, we end this subsection with some minor notes. First, because of publication lag of the monthly inflation rate in Japan, the latest inflation rate that the forecasters in the *ESP Forecast* survey can observe is the value reported two months before the forecast date. To avoid the confusion about the notation, we simply denote the latest value in the period t as π_t. Second, in the data set, the forecasters experienced three times base-revisions for the consumer price index in 2005, 2010, and 2015. In every revision year, the index with the revised base is newly reported from August. In the *ESP Forecast* survey, the forecasters are asked to report the forecast for the CPI change with the base before the revision until August, and to report the one with the revised base from September. We carefully choose the data for the lagged monthly inflation rate so that it is consistent with the values which the forecasters may actually use to form their forecasts.

2.4 Empirical Results

2.4.1 Benchmark case

In our sample, the average monthly frequency of information updates is 48 percent, which corresponds to the degree of sticky information of around 14 percent at a quarterly frequency. This number is smaller than the 54 percent obtained by Coibion and Gorodnichenko [13] for the US and 40 percent by Nakazono [61] for Japan. The difference may result from the direct and indirect estimation methods of sticky information structure.

The model selection method yields the AR model of order $p = 2$ so our empirical model is (2.1) combined with

$$\pi^{i,AR}_{t+1|t} = (1 - \beta)(\Pi^*_i + \alpha QQE_t) + \phi_1 \pi_t + \phi_2 \pi_{t-1}. \tag{2.3}$$

In what follows, we refer to this benchmark case as specification 1 and the results of estimation are provided in the first column of Table **??**. Here, the mean of Π^*_i among all agents is denoted by Π^*. The estimate of α is 0.76 percent, which is positive and significant. Thus, the introduction of QQE raised the long-run inflation expectations from 0.43 percent ($= \Pi^*$) to 1.19 percent ($= \Pi^* + \alpha$) on average. The estimated persistence of inflation is very high with the sum of AR coefficients β being 0.94. The overidentifying restrictions are not rejected by the J test statistics and the validity of the model is justified.

Figure 2.2 displays the estimated distribution of Π_i^* and $\Pi^* + \alpha\alpha QQE_t$. The blue and red dotted lines in the figure depict the average value of the long-run inflation expectations among the forecasters, before and after the adoption of QQE regime. The figure shows that more than half of the forecasters had long-run expectations of smaller than 0.5% in their mind before the QQE regime. However, after the introduction of QQE by the BOJ, almost all forecasters have started to trust the inflation in Japan to be converged in the level higher than 1%. The policy regime change in 2013 critically shifted the long-run inflation expectations of all forecasters, succeded to cure the sentiment by the forecasters and make them have a positive impression about the future process of inflation.

We also consider the following two alternative specifications. First, we introduce the heterogeneity of AR coefficients to (2.3) as

$$\pi_{t+1|t}^{i,AR} = (1-\beta)(\Pi_i^* + \alpha QQE_t) + \phi_{1i}\pi_t + \phi_{2i}\pi_{t-1} \tag{2.4}$$

with the restriction that the expected persistence of the inflation is common across agents, or the sum of AR coefficient is $\beta = \phi_{1i} + \phi_{2i}$ (specification 2). Second, heterogeneity of the QQE impact coefficients, instead of AR coefficients, can be introduced to (2.3) as

$$\pi_{t+1|t}^{i,AR} = (1-\beta)(\Pi_i^* + \alpha_i QQE_t) + \phi_1\pi_t + \phi_2\pi_{t-1} \tag{2.5}$$

where α_i captures the individual-specific shift of long-run inflation expectations (specification 3). The results of two specifications shown in Table **??** are very close to those of specification 1 (α denotes the mean of α_i for specification 3).

Figure 2.3 shows the distribution of inflation expectations based on the specification 2. The implication is almost the same as the specification 1. Figure 2.4, which is based on the specification 3, suggests some interesting aspects about the recent movement of long-run inflation expectations. In this specification, the degree of shift in inflation expectations is allowed to be different among the individuals. In the pre-QQE periods, variability of inflation expectations are very large. In contrast, about the post-QQE periods, the figure shows that long-run inflation expectations of forecasters have massed around the 1% point. The results suggests the possibility that the heterogeneity about the perspective for the future inflation path has shrinked or in other words, QQE succeeds to "anchor" the long-run inflation expectations of forecasters.

2.4.2 Model with Smooth Transition

It should be noted that our estimates of the long-run inflation expectations are average values of individual forecasts at the infinite horizon. In contrast, for every six months, the *ESP Forecast* includes a special survey about medium-run (2-6 fiscal years ahead) and long-run (7-11 fiscal years ahead) inflation forecasts. Figure 2.5 shows our estimated infinite-horizon inflation forecasts in specification 1 by a solid line, along with medians of medium-run (long-run) forecasts in biannual survey by a square (diamond). As shown in the figure, our estimated shift of long-run inflation expectations is in line with the changes in biannual survey forecasts. One noticeable point, however, is that biannual survey forecasts tend to be lower in later years. In all specifications so far, the introduction of QQE is assumed to have a permanent effect on the long-run inflation expectations.

To incorporate the temporary effect of QQE in addition to its permanent effect, a smooth transition variant of the AR model is introduced as

$$\pi_{t+1|t}^{i,AR} = (1-\beta)\left[\Pi_i^* + \left\{\alpha + e^{-\delta(t-T^*)}\gamma\right\} QQE_t\right] + \phi_1\pi_t + \phi_2\pi_{t-1} \tag{2.6}$$

where T^* denotes the time subscript at the introduction of QQE (specification 4). In this specification, α captures the permanent effect, while γ captures the temporary effect. The results are reported in Table **??**, along with the case when ϕ_1 and ϕ_2 in (2.6) are replaced by ϕ_{1i} and $\phi_{2i} = \beta - \phi_{1i}$ (specification 5) and with the case when α and γ in (2.6) are replaced by α_i and γ_i (specification 6).

Overall, adding the temporary effect results in a larger initial impact of QQE. For example, the results of specification 4 imply that long-run inflation expectations increased on average from 0.41 percent ($= \Pi^*$) to 1.61 percent ($= \Pi^* + \alpha + \gamma$). However, for all estimates, the sizes of temporary component γ are larger than those of the permanent component α (α and γ denote the means of α_i and γ_i for specification 6). To evaluate the plausibility of the models with and without temporary effects, we report model selection criteria by Andrews (1999) for specifications 1 to 6. As shown in the table, both GMM-AIC and GMM-BIC favor the specifications with a temporary effect. Furthermore, both criteria are minimized with specification 4.

Figure 2.5 shows the estimated change in the long-run inflation expectation of specification 4 by a dashed line. It shows that this model well captures the initial impact of QQE as well as recent decline of long-run expectations. Based on a 95 percent confidence interval of long-run inflation expectations, the official inflation target of 2 percent is included at the impact (with the upper-bound being 2.14 percent). In contrast, the 2 percent target is out of the confidence interval at the most recent period in the sample (with the upper-bound being 1.67 percent).

2.5 Robustness check

In our model, the forecasters are assumed to observe the past realization of monthly inflation rate and form their forecasts according to (2.1) in each month. In Japan, there is another source of information that may be useful for forecasting monthly inflation rate. In every month, *Ministry of Economy, Trade and Industry* reports "Indices of Industrial Production (IIP)", which tries to provide rough estimates of present economic situation in Japan by reporting a comprehensive indicator of the domestic production activities such as mining and manufacturing.

The main part of IIP consists of four categories: production, shipments, inventory and inventory ratio. "Production" index is the index which shows the level of the entire mining and manufacturing activities. If the economy is in the boom, domestic and foreign demand will increase and to meet such demand, domestic production will become more active and the index will take a higher value. When the economy goes into a recession, the things go opposite. "Shipments" index indicates the status of shipment of mining and manufacturing products from factories to the economy. Shipments generally increase as demand for such products grows with an economic expansion, whereas an economic slowdown leads to decline in it. "Inventory" index shows the level of inventory of mining and manufacturing products remaining in the factories of the producers. It falls as shipment rises during a period of economic expansion, and after that, starts to be accumulated by activating production. In contrast, inventory level rises as shipment declines during a recession, which later causes adjustment of inventory mainly by suppressing production. According to such inventory cycle, it is said to move slightly later than the actual performance of the economy. Finally, "Inventory ratio" index combines information about movements of shipments and inventory of mining and manufacturing products. Relatively high value of this index indicates the start of accumulating phase in inventory, which implies the economy reaching a peak of its performance. On the other hand, a low value of the index indicates the start of adjusting phase in inventory, which implies the economy getting out of a cyclical bottom. As such, the index is considered to be important as a lead indicator of economic performance in Japan.

As the robustness check for our empirical analysis, we here add the four categories of these indices into the all six specifications above. The results are summerized in the Table **??** to **??**. As shown in the tables, the coefficient on the IIP variable is insignificant in all cases, whereas the significance of the main explanatory variable remains as in the previous regressions. The estimated values of long-run inflation expectations and the effect of QQE are virtually the same as in the Table **??**. This implies that the most recent realization of inflation rate contains enough information for fitting the common or non-heterogenious part of inflation forecasts reported in the *ESP forecast*.

2.6 Conclusion

In this chapter, we investigate whether QQE regime in Japan critically impacts the long-run inflation expectations or not by using "*ESP Forecast*" survey data, which is a monthly survey for economists in Japan conducted by the Japan Center for Economic

Research.

In summary, our estimation result implies that the introduction of QQE in April 2013 actually gave the significant impact to the professional forecasters and succeded to raise the long-run inflation expectations of them toward the target of 2%. In particular, the forecasters who had the long-run expected inflation around 0.5%, have changed their mind to trust the inflation in Japan to be converged in the level around 1%. When focusing on the temporary effect of QQE, the change can be seen more clealy that long-run inflation expectations increased on average from 0.41 percent to 1.61 percent. Thus, our results suggest that the aggressive monetary policies in recent years are at least partially successful for providing a good startpoint to escape from the deflationary regime and to transform the deflationary mind of the private agents in Japan.

However, at the same time, our empirical results also suggest that the effect is not sufficient to achieve the 2% inflation target in near future and furthermore, it has deteriorated in recent years. In particular,the average value of estimated long-run inflation expectations, which increases from 0.425% to 1.467% soon after the introduction of QQE, decreases to 1.3% after January 2016. Of course we can not do the overall assessment of the recent policy only from our analysis, the result shows the possibility of challenging environments for the Bank of Japan that achieving the original commitment of the 2% stable inflation.

	specification					
	(1)	(2)	(3)	(4)	(5)	(6)
Π^*	0.427**	0.417**	0.408**	0.412**	0.403**	0.405**
	(0.028)	(0.024)	(0.012)	(0.034)	(0.029)	(0.033)
α	0.762**	0.745**	0.724**	0.103**	0.102**	0.101**
	(0.113)	(0.106)	(0.044)	(0.034)	(0.035)	(0.012)
β	0.935**	0.892**	0.923**	0.902**	0.919**	0.915**
	(0.233)	(0.091)	(0.178)	(0.265)	(0.083)	(0.208)
γ				1.095**	0.992**	0.903**
				(0.269)	(0.251)	(0.107)
δ				0.009**	0.010**	0.006*
				(0.001)	(0.002)	(0.003)
J test	0.493	0.543	0.444	0.754	0.718	0.508
GMM-AIC	−19.54	−20.37	−18.72	−25.78	−25.12	−21.79
GMM-BIC	−167.09	−167.92	−166.26	−173.33	−172.66	−169.34

Notes: * and ** show that coefficients are significant at the 5% and 1% level, respectively. Numbers in parenthesis are cluster-robust standard errors. J test shows the *p*-values of the test for the overidentifying restrictions. GMM-AIC and GMM-BIC are model selection criteria of Andrews (1999).

Table 2.1: Regression results

	specification					
	(1)	(2)	(3)	(4)	(5)	(6)
Π^*	0.427**	0.417**	0.408**	0.412**	0.403**	0.405**
	(0.028)	(0.024)	(0.012)	(0.034)	(0.029)	(0.033)
α	0.762**	0.745**	0.724**	0.103**	0.102**	0.101**
	(0.113)	(0.106)	(0.044)	(0.034)	(0.035)	(0.012)
β	0.936**	0.891**	0.925**	0.902**	0.919**	0.915**
	(0.237)	(0.097)	(0.188)	(0.269)	(0.088)	(0.212)
γ				1.095**	0.992**	0.903**
				(0.269)	(0.251)	(0.107)
δ				0.009**	0.010**	0.006*
				(0.001)	(0.002)	(0.003)
θ	0.194	0.193	0.198	0.086	0.086	0.085
	(1.029)	(1.029)	(1.030)	(0.975)	(0.974)	(0.974)
J test	0.493	0.543	0.444	0.754	0.718	0.508
GMM-AIC	−17.62	−18.44	−16.79	−23.86	−23.20	−19.87
GMM-BIC	−157.39	−158.22	−156.56	−163.63	−162.96	−159.64

Notes: * and ** show that coefficients are significant at the 5% and 1% level, respectively. Numbers in parenthesis are cluster-robust standard errors. J test shows the p-values of the test for the overidentifying restrictions. GMM-AIC and GMM-BIC are model selection criteria of Andrews (1999).

Table 2.2: Regression results with IIP (Production index)

	specification					
	(1)	(2)	(3)	(4)	(5)	(6)
Π^*	0.427**	0.417**	0.408**	0.412**	0.403**	0.405**
	(0.028)	(0.024)	(0.012)	(0.034)	(0.029)	(0.033)
α	0.762**	0.745**	0.724**	0.103**	0.102**	0.101**
	(0.113)	(0.106)	(0.044)	(0.034)	(0.035)	(0.012)
β	0.939**	0.898**	0.923**	0.904**	0.919**	0.918**
	(0.273)	(0.099)	(0.176)	(0.267)	(0.083)	(0.213)
γ				1.095**	0.992**	0.903**
				(0.269)	(0.251)	(0.107)
δ				0.009**	0.010**	0.006*
				(0.001)	(0.002)	(0.003)
θ	0.058	0.057	0.054	0.022	0.022	0.022
	(0.998)	(0.998)	(0.997)	(0.993)	(0.9993)	(0.993)
J test	0.493	0.543	0.444	0.754	0.718	0.508
GMM-AIC	−17.34	−18.17	−16.52	−23.58	−22.91	−19.58
GMM-BIC	−157.38	−158.21	−156.55	−163.62	−162.95	−159.63

Notes: * and ** show that coefficients are significant at the 5% and 1% level, respectively. Numbers in parenthesis are cluster-robust standard errors. J test shows the *p*-values of the test for the overidentifying restrictions. GMM-AIC and GMM-BIC are model selection criteria of Andrews (1999).

Table 2.3: Regression results with IIP (Shipments index)

	specification					
	(1)	(2)	(3)	(4)	(5)	(6)
Π^*	0.426**	0.417**	0.407**	0.413**	0.404**	0.406**
	(0.029)	(0.027)	(0.014)	(0.037)	(0.033)	(0.038)
α	0.760**	0.743**	0.721**	0.103**	0.102**	0.101**
	(0.118)	(0.107)	(0.052)	(0.033)	(0.035)	(0.012)
β	0.947**	0.883**	0.913**	0.909**	0.919**	0.911**
	(0.272)	(0.096)	(0.182)	(0.270)	(0.081)	(0.207)
γ				1.080**	0.972**	0.889**
				(0.270)	(0.250)	(0.107)
δ				0.009**	0.010**	0.006*
				(0.001)	(0.002)	(0.003)
θ	0.434	0.427	0.420	0.398	0.393	0.393
	(3.090)	(3.088)	(3.087)	(3.081)	(3.080)	(3.080)
J test	0.494	0.544	0.445	0.755	0.719	0.509
GMM-AIC	−17.35	−18.18	−16.53	−23.59	−22.92	−19.59
GMM-BIC	−157.39	−158.22	−156.56	−163.63	−162.96	−159.64

Notes: * and ** show that coefficients are significant at the 5% and 1% level, respectively. Numbers in parenthesis are cluster-robust standard errors. J test shows the p-values of the test for the overidentifying restrictions. GMM-AIC and GMM-BIC are model selection criteria of Andrews (1999).

Table 2.4: Regression results with IIP (Inventories index)

	specification					
	(1)	(2)	(3)	(4)	(5)	(6)
Π^*	0.426**	0.416**	0.408**	0.412**	0.403**	0.405**
	(0.030)	(0.025)	(0.015)	(0.034)	(0.029)	(0.033)
α	0.758**	0.741**	0.722**	0.103**	0.102**	0.101**
	(0.124)	(0.109)	(0.052)	(0.034)	(0.035)	(0.012)
β	0.887**	0.862**	0.892**	0.869**	0.918**	0.916**
	(0.243)	(0.095)	(0.216)	(0.255)	(0.083)	(0.207)
γ				1.090**	0.988**	0.899**
				(0.278)	(0.261)	(0.108)
δ				0.009**	0.010**	0.006*
				(0.001)	(0.002)	(0.003)
θ	0.423	0.423	0.420	0.209	0.209	0.207
	(0.932)	(0.932)	(0.931)	(0.914)	(0.914)	(0.912)
J test	0.494	0.544	0.445	0.754	0.718	0.508
GMM-AIC	−17.38	−18.21	−16.56	−23.62	−22.95	−19.62
GMM-BIC	−157.43	−158.26	−156.6	−163.67	−163.00	−159.68

Notes: * and ** show that coefficients are significant at the 5% and 1% level, respectively. Numbers in parenthesis are cluster-robust standard errors. J test shows the p-values of the test for the overidentifying restrictions. GMM-AIC and GMM-BIC are model selection criteria of Andrews (1999).

Table 2.5: Regression results with IIP (Inventories ratio index)

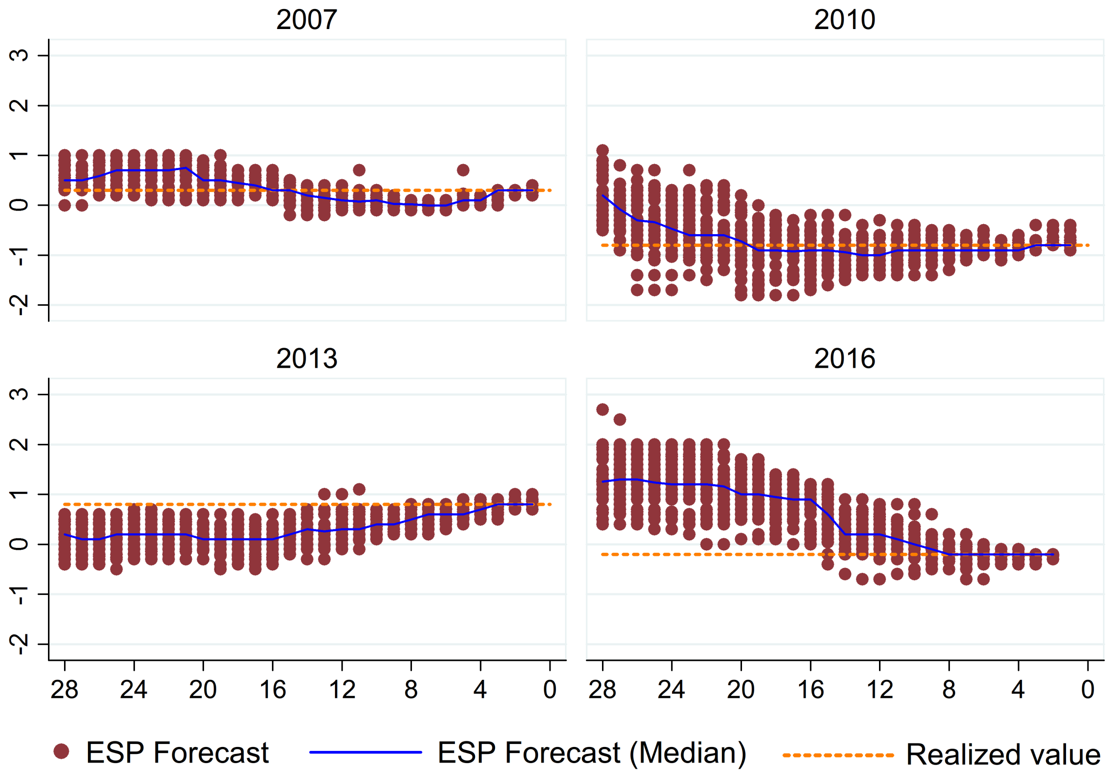

Fig. 2.1: Distributions of individual inflation forecasts

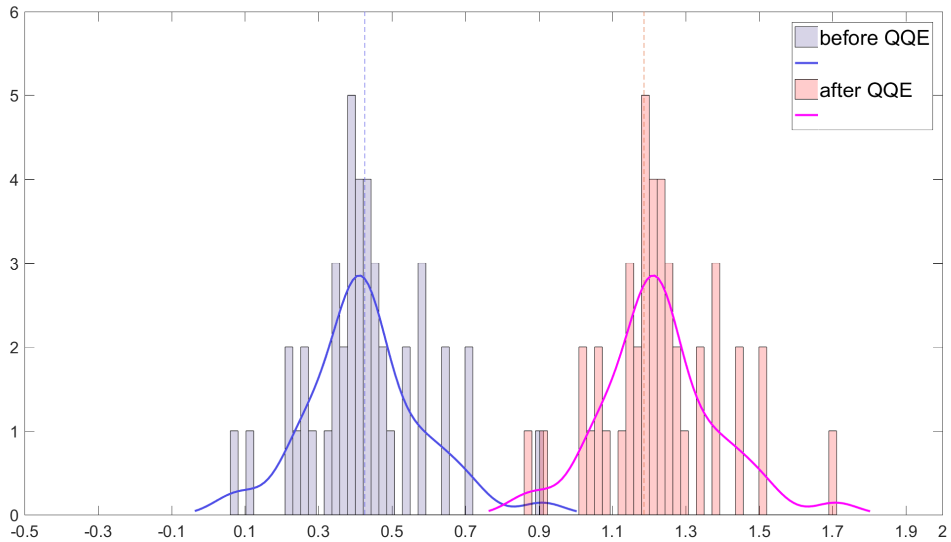

Fig. 2.2: Distribution of long-run inflation expectations in (1)

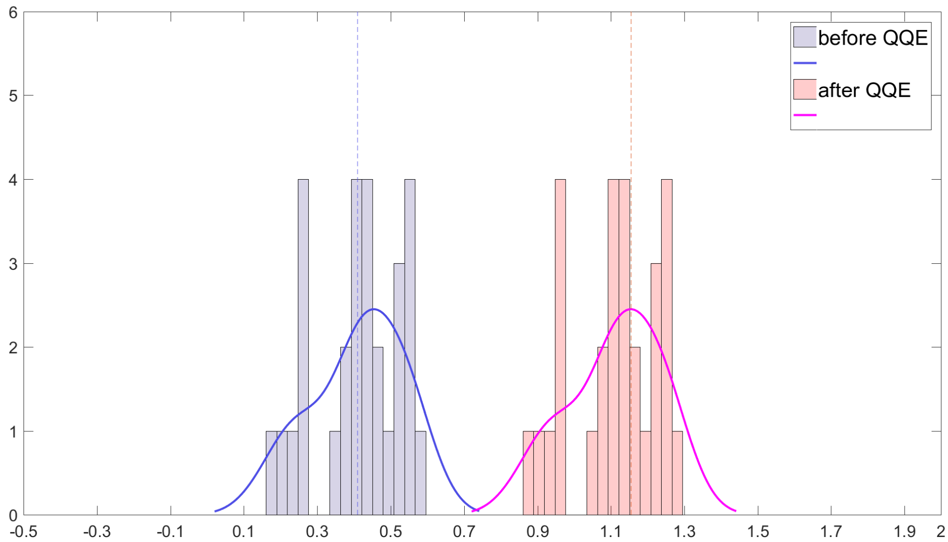

Fig. 2.3: Distribution of long-run inflation expectations in (2)

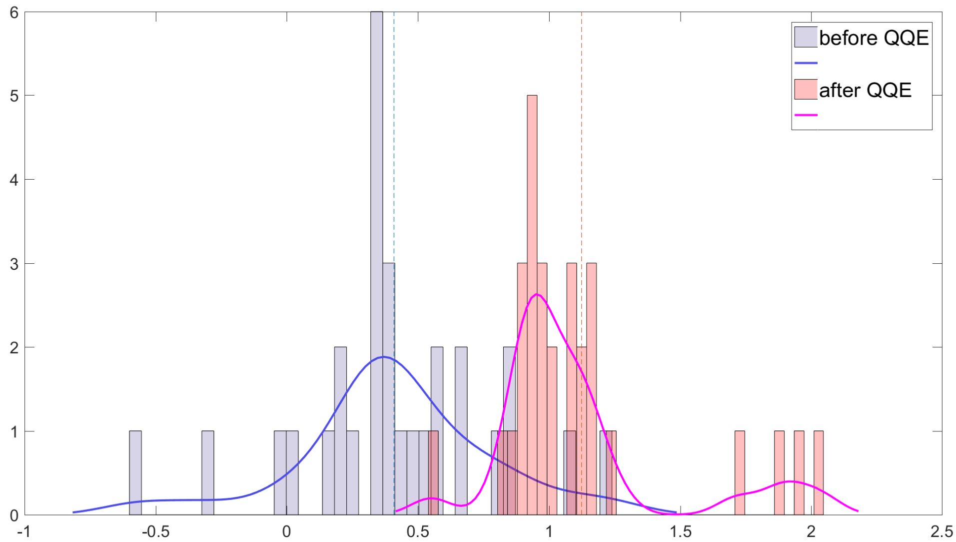

Fig. 2.4: Distribution of estimated long-run inflation expectations in (3)

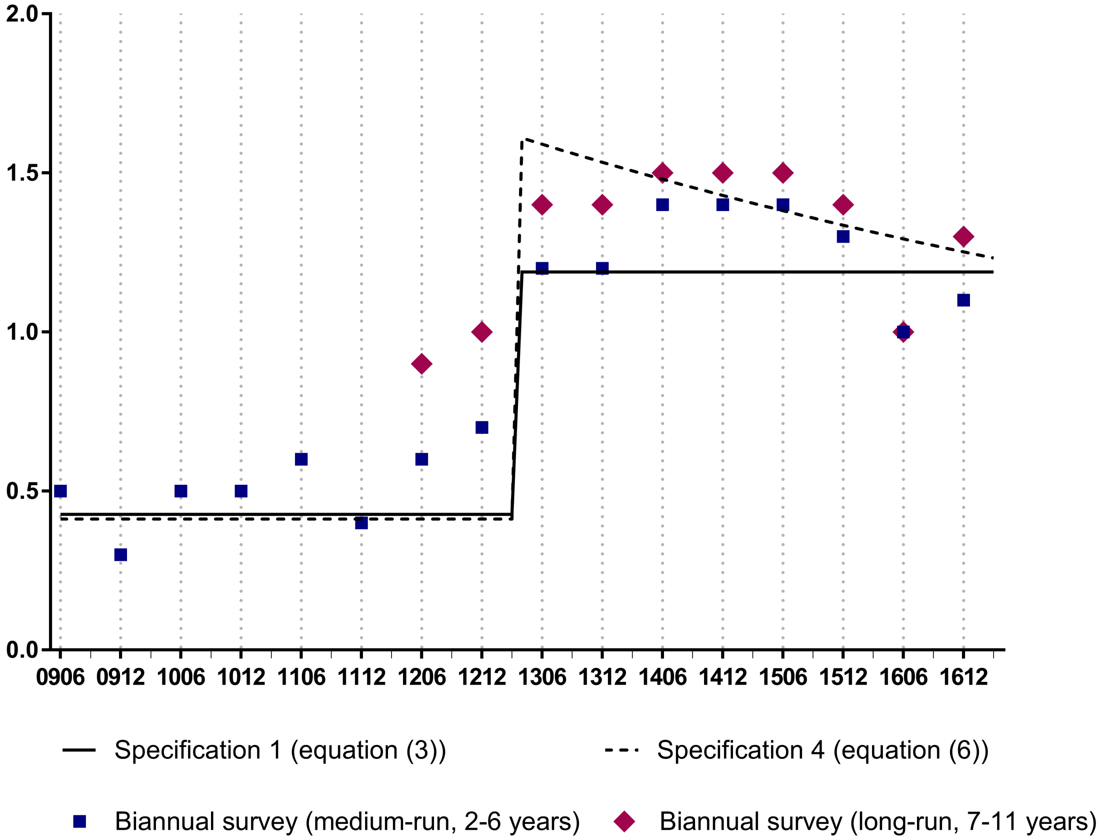

Fig. 2.5: Estimated long-run inflation expectations and biannual survey forecasts

Chapter 3

The Effects of QQE on the Phillips curve in Japan

3.1 Introduction

In literature, a number of studies argued that an explicit inflation targeting regime provides for less uncertainty about future inflation rates by anchoring private agents' inflation expectations successfully.[1] However, the argument is based on an implicit assumption that the central bank can achieve the explicit inflation target appropriately. It is far from clear whether the argument still holds true when the central bank faces a serious difficulty in achieving its explicit inflation target. Under prolonged deflation, the Bank of Japan (BOJ) is one of central bank that has adopted an explicit inflation target but faced a serious difficulty in achieving the target. The purpose of this chapter is to explore whether the BOJ's explicit inflation target could anchor inflation expectations successfully under the special environments in Japan.

Soon after the BOJ announced the 2% inflation target in the consumer price index (CPI) in January 2013, the CPI inflation rate, which had stagnated below zero, rose substantially. In April 2014, it reached 1.5% when including energy and 0.8% when

[1]See, for example, Bernanke and Mishkin [6], Mishkin and Schmidt-Hebbel [58], Bernanke [5], Levin et al. [51], Dincer and Eichengreen [19], Crowe and Meade [16], Dincer and Eichengreen [20], Crowe [15] and Dincer and Eichengreen [21].

excluding energy. htpbowever, it started to decline in the latter half of 2014. Reflecting oil price decline, it fell below zero in July 2015 when including energy. Even when excluding energy, it fell below zero in February 2017 (Figure 1). It is thus likely that the role of the explicit inflation target might have faced structural changes in anchoring inflation expectations in Japan.

To explore possible structural changes, the following analysis estimates cross-section Phillips curves by using Japanese forecaster-level data of "*ESP Forecast*" which is collected by Japan Center of Economic Research. *ESP Forecast* is a monthly survey on the macroeconomic outlook of Japan's economy including real GDP growth rate, the Core CPI inflation rate, the yen-dollar exchange rate, and NY WTI crude oil futures. Estimating the cross-section Phillips curves for alternative periods derives how the anchor of inflation expectations changed over time in Japan.

Our main findings are threefold. First, we find the way of forecasters' expectation formation is actually consistent with the expectation-augumented Phillips curve. Second, we capture the significant structural changes in this Phillips curve which occurs after the introduction of QQE. In particular, our results indicate that the BOJ's inflation targeting policy makes the inflation forecast more sensitive to the GDP growth forecast, or in other words, the slope of the Phillips curve steeper. The result here is in stark contrast to the literature which reports flattening Phillips curve in Japan by using pre-QQE periods data set.[2] This paper uses more recent data which includes the post-QQE period, update their results and suggest the possibility of recovered relationship between output and inflation in Japan. Third, the estimated anchor of private inflation expectations, which has a feature of medium-run inflation expectations, changes dra-

[2] For example, see De Veirman [17], Fuhrer et al. [24], and Kaihatsu et al. [38].

matically in between pre and post QQE periods. Before the BOJ storongly commited to the achievement of 2% inflation target in April 2013, the estimated anchor of private inflation expectations was negative. But after the announcement, the new target and the policy thereafter increased the estimated anchor of inflation expectations significantly. This implies that the announcement of 2% target was successful in anchoring inflation expectations in positive values. However, the estimated anchor has never reached the target. More importantly it declined around 2015 when it turned out that the 2% target would not be feasible in the near future. It is likely that when Japanese forecasters perceived that the BOJ faced difficulties in fulfilling the commitment, they came to place little weight on the anchor of inflation expectations. The result implies that an explicit inflation targeting regime provides for less uncertainty about future monetary policy actions only when it is a feasible target.

In literature, there are both positive and negative evaluations on the BOJ's dramatic policy changes in Japan. Fukuda [28] showed that financial market expectations change dramatically after Prime Minister Abe announced a new monetary policy regime in late 2012. Hattori and Yetman [33] find that after the BOJ announced the 2% inflation target, the estimated anchors across forecasters have tended to rise, along with the dispersion in estimates across forecasters. In contrast, Fujiwara et al. [27] find no sizable difference in perceptions of CPI inflations before and after the introduction of new monetary policy regime. This chapter contributes to these literature by estimating how the formation of inflation expectaion in various horizons by the private agents in Japan have changed in recent years.

The chapter proceeds as follows. Section 2 overviews how the BOJ's monetary policy and its targeted inflation rate changed and Section 3 explains the "*ESP Forecast*" we use in the empirical exercises. Section 4 formulates an expectations-augmented Phillips curve. After discussing how to derive the anchor of inflation expectations by using the data of *ESP Forecast*, Section 5 shows the estimation results of our cross-section Phillips curves. Section 7 derives the anchor of inflation expectations and Section 8 checks robustness of our estimation. Finally, Section 9 concludes.

3.2 Inflation targeting in Japan

Before moving to the estimation, this section briefly overviews how the BOJ's monetary policy and its targeted inflation rate changed after the Global Financial Crisis (GFC) in 2008 and how the BOJ suffers for achieving the inflation target from the two aspects: the change of BOJ's point estimates of core CPI inflation rate and the repeated delays in achieving the target.

As summarized in Table 3.1, the BOJ adopted a series of unconventional monetary policies after the GFC. In particular, after the introduction of the "Quantitative and Qualitative Monetary Easing (QQE)" on April 4, 2013, the BOJ showed a highly aggressive stance in its policy. It expanded the QQE on October 31, 2014 and introduced two new frameworks, termed "QQE with a Negative Interest Rate," on January 29, 2016 and "QQE with Yield Curve Control" on September 21, 2016.

The BOJ also increased its targeted CPI inflation rate (the year-on-year rate of change in CPI) after the GFC. Before the GFC, most of policy board members clarified their "understanding of medium- to long-term price stability", which was understood as the implicit inflation target of BOJ, were "in the range approximately between 0 and 2%" (April 2009). But on December 18, 2009, the BOJ clarified that it was changed to the level around 1% and declared that it would never tolerate the inflation rate equal to or below 0%. Further, it announced introducing an explicit 2% inflation target in the CPI on January 22, 2013. Since the previous target was an implicit rate at around 1%, the announcement of the explicit 2% inflation target was recognized as a dramatic change in its commitment. In particular, when introducing the QQE on April 4, 2013, the BOJ made a commitment that it would achieve the CPI price stability target of 2% "at the earliest possible time, with a time horizon of about two years."

After announcing the 2% inflation target, the BOJ increased its estimates (or forecasts) on future inflation rates substantially. Table 3.2 summarizes the BOJ's point estimates of core CPI inflation rate after the GFC. In its *Outlook for Economic Activity and Prices*, the BOJ announces the point estimates of policy board members' forecasts four times a year: January, April, July, and October (or November). As the table shows, the reported point estimate of the core CPI inflation rate in fiscal year T starts in April of year $T-2$ and continues through to April in year $T+1$, so that there are basically 12 forecasts for the same fixed event. Before $T = 2012$, the estimate starts in October of year $T-2$ through to April in year $T+1$, so that there are 10 forecasts for the same fixed event.

The table shows two interesting features. First, the initial point estimate is in marked contrast before and after announcing the 2% inflation target. That is, the initial point estimate in October of year $T-2$ was far below 1% before $T = 2014$, while the initial point estimate in April of year $T-2$ was around 2% after $T = 2015$. This implies that corresponding to the introduction of explicit 2% inflation target, the BOJ's initial point estimates of the CPI inflation rate have been raised dramatically. Second, the posterior accuracy of the initial point estimate declined substantially after announcing the 2% inflation target. Before $T = 2014$, the difference between the initial point estimate in October of year $T-2$ and the final point estimate in April of year $T+1$ was less than 0.5% except for $T = 2012$. In contrast, after $T = 2015$, the initial point estimate in April of year $T-2$ overestimated the final point estimate substantially. The overestimation amounted to 1.9% points in 2015 and 2.4% points in 2016. One of the possible explanations for the recent increases of forecast errors is that the BOJ may use the point estimate of future inflation rates as a commiting or a communicating device rather than the literal "forecasts" for the future. By reporting bullish projections in the long-horizon, the BOJ may try to show a strong will to achieve the target to the private agents. Despite scuh strong commitment and dramatic increases in the monetary base, the QQE and the policy thereafter could not achieve the price stability target of 2% (excluding the direct effects of the consumption tax hikes).

Since April 2015, the BOJ has changed its projected timing of reaching around 2% frequently. Until October 2014, its *Outlook for Economic Activity and Prices* stated that the projected timing would be "in or around fiscal 2015". But it changed the timing to "around the first half of fiscal 2016" in Aril 2015, to "around the second half of fiscal 2016" in October 2015, to "around the first half of fiscal 2017" in January 2016, to "during fiscal 2017" in April 2016, to "around fiscal 2018" in November 2016, and to "around fiscal 2019" in July 2017. The frequent changes in the projected timing of reaching around 2% indicate the serious difficulties in achieving the target the BOJ has been faced.

3.3 ESP Forecast

The purpose of this chapter is to explore whether the BOJ's introduction of explicit inflation targeting regime could anchor inflation expectations by using "*ESP Forecast*". *ESP Forecast* is a monthly survey on the outlook of Japan's economy. Around 40 leading forecasters from private institutes in Japan participate in this survey. The Japan Center for Economic Research (JCER) conducts the survey since January 2005. The survey is conducted around the beginning of each month and its result is publicized in the middle of the month. The surveyed macroeconomic variables include growth rate of real GDP and its components, growth rate of industrial production index, current account, the Core CPI inflation rate (year-on-year), unemployment rate, Nikkei Average Stock Price Index, the yen-dollar exchange rate, and NY WTI crude oil futures.

Our data consists of the "fixed-event" type of forecasts, which collects a panel of forecasts for a set of outturns of a series at varying horizons prior to each outturn. For most variables, when quoting forecasts of the value in fiscal year T, the forecast origin starts in January of year $T-1$ and continues through to May of year $T+1$, so that there are 29 horizons forecasts for the same fixed event. In addition to this, only for real GDP growth rate and the Core CPI inflation rate, when quoting forecasts fot the value in fiscal year $T = 2015, 2016, 2017, 2018$ and 2019, the forecast origin starts in June of year $T-2$ and continues through to May of year $T+1$. Thus for real GDP growth rate and the Core CPI inflation rate in fiscal year T, there are 34 forecasts for the same fixed event after $T = 2015$.[3]

Fixed-event forecasts generally have a seasonal property that the number of forecast

[3] Even for real GDP growth rate and the Core CPI inflation rate, the forecast origin started in January of year $T-1$ before $T = 2014$.

horizons is different depending on in which month the forecast is quoted. *ESP Forecast* also has a property that the target events are different depending on in which month the forecast is quoted. When the forecast origin is from January to May in year T, the forecasted fixed event is the value in fiscal years $T-1$, T, and $T+1$. In contrast, when the forecast origin is from June to December in year T, the forecasted fixed event is the value in fiscal years T and $T+1$ for most variables and the value in fiscal years T, $T+1$, and $T+2$ for real GDP growth rate and the Core CPI inflation rate after $T = 2013$.

Table 3.3 summarizes basic statistics of the forecasted real GDP growth rate and after-tax core CPI inflation rate from fiscal year 2005 to 2019. It reports average and standard deviation of the forecasted fiscal year T's values quoted in January in year $T-1$, July in year $T-1$, January in year T, July in year T, and January in year $T+1$. For both real GDP growth rate and core CPI inflation rate, the average forecasted value shows substantial variations between January in year $T-1$ and January in year $T+1$. In contrast, the standard deviation declines as the forecast origin approaches the forecasted year. This implies that the forecasters revise their forecasts by incorporating new information and eventually form almost homogeneous forecast. However, the standard deviations decline only modestly until July in year T. This suggests that the fixed event forecasts remain heterogeneous until the realized values become available to the forecasters. Comparing the standard deviations between real GDP growth rate and core CPI inflation rate, the forecasted real GDP growth rates had been more heterogeneous than the forecasted core CPI inflation rate until $T = 2014$. However, after $T = 2015$, the forecasted core CPI inflation rate became more heterogeneous than the forecasted real GDP growth rates in January in year $T-1$ and July in year $T-1$. This suggests that the BOJ's dramatic policy changes reduced heterogeneity of medium-term GDP growth expectations but increased heterogeneity of medium-term inflation expectations.

3.4 Baseline model

In the following sections, we explore whether the BOJ's explicit inflation targeting regime could change the inflation expectations of private agents in Japan through estimating cross-section Phillips curves. In the analysis, we consider an expectations-augmented Phillips curve

$$\Pi_t = \Pi_t^e + \alpha(\ln Y_t - \ln Y_t^*) + U_t, \tag{3.1}$$

where Π_t denotes the inflation rate in the period t, Y_t is the real output and Y_t^* is the potential real output, and U_t denotes the supply shock. The equation above explains the movement of inflation rates by the three components: the output gap $\ln Y_t - \ln Y_t^*$, supply shocks U_t, and the expected inflation rate Π_t^e. The term Π_t^e represents the expected underlying inflation rate which is independent of output gap and supply shocks. Note that Π_t^e is different from the average expected inflation rate because the expected effects of output gap and supply shocks are reflected in $\alpha(\ln Y_t - \ln Y^*)$ and U_t, respectively. Since it has a feature of medium-run inflation rate, we call Π_t^e as "the anchor of inflation expectations".

In our analysis, we assume that the forecasters form their inflation expectations by using equation (3.1). We also assume that when forecasting the macroeconomic values in the period t, they are based on both public and private information available in the period $t-1$. Defining the individual forecaster j's expectation operator based on information in $t-1$ by $E_{j,t-1}$, we obtain

$$E_{j,t-1}\Pi_t = \Pi_t^e + \alpha E_{j,t-1}(\ln Y_t - \ln Y_t^*) + E_{j,t-1}U_t \tag{3.2}$$

In the above equation, it is worthwhile to note that there is no expectation operator $E_{j,t-1}$ for Π_t^e. This is because the anchor of inflation expectations is assumed to be based only on public information in $t-1$, so that it is common for all forecasters. We may interpret that superscript e denotes the expectation operator based on public information in time $t-1$. The forecast for the output gap in the period t can be decomposed as

$$E_{j,t-1}(\ln Y_t - \ln Y^*) = E_{j,t-1}\Delta \ln Y_t - E_{j,t-1}\Delta \ln Y_t^* + (\ln Y_{t-1} - \ln Y_{t-1}^*), \tag{3.3}$$

where $\Delta \ln Y_t \equiv \ln Y_t - \ln Y_{t-1}$ and $\Delta \ln Y_t^* \equiv \ln Y_t^* - \ln Y_{t-1}^*$. For simplicity, we here assume that the potential output growth from the current to the next period is the public information for all forecasters.[4] Then by substituting equation (3.3) into equation (3.2), we obtain

$$E_{j,t-1}\Pi_t = \left\{\Pi_t^e - \alpha\Delta \ln Y_t^* + \alpha(\ln Y_{t-1} - \ln Y_{t-1}^*)\right\} + \left\{\alpha E_{j,t-1}\Delta \ln Y_t + E_{j,t-1}U_t\right\}, \tag{3.4}$$

Equation (3.4) implies that forecaster j's inflation expectation formed in period $t-1$ consists of two parts. One is $\left\{\Pi_t^e - \alpha\Delta \ln Y_t^* + \alpha(\ln Y_{t-1} - \ln Y_{t-1}^*)\right\}$, which is publicly known and common for all j. It is the sum of the anchor of inflation expectations and α

[4]The main resason for setting the assumption here is the limitation of available data. *ESP Forecast* does not ask the question about the potential output, so we cannnot obtain the individual-specific forecasts for $\Delta \ln Y_t^*$.

times realized output gap in period $t-1$. Another component is $\{\alpha E_{j,t-1}\Delta \ln Y_t + E_{j,t-1}U_t\}$, which is heterogeneous across j. It is the sum of the α times the expectaion for GDP growth rate by the forecaster j's and forecaster j's supply shock expectations. Using equation (3.4), the following sections investigate the changes of the anchor of inflation expectations Π_t^e and the slope of the Phillips curve α in recent years.

3.5 Regression analysis

3.5.1 The Estimated Equation

Based on the model in the previous section, we estimate the following cross-section equation for each period τ:

$$F_{j,\tau}\Pi_{\tau+1} = \textit{constant term} + \alpha F_{j,\tau}\Delta \ln Y_{\tau+1} + \sum_{i=1}^{N} \beta_\tau^i F_{j,\tau}\Delta X_\tau^i + \varepsilon_{j,\tau}, \tag{3.5}$$

where $F_{j,\tau}\Pi_{\tau+1}$, $F_{j,\tau}\Delta \ln Y_{\tau+1}$, and $F_{j,\tau}\Delta X_\tau^i$ are the forecaster j's forecast for inflation rate, GDP growth rate, and supply shocks, respectively. The operator $F_{j,\tau}$ denotes the forecast formed in period τ for the value in period $\tau+1$.

Equation (3.5) is the *ESP Forecast* version of equation (3.4), where the constant term is the sum of the anchor of inflation expectations $\Pi_{\tau+1}^e$ and realized output gap term $\alpha(\ln Y_\tau - \ln Y_\tau^*)$.[5] In *ESP Forecast*, we can observe both $F_{j,\tau}\Pi_{\tau+1}$ and $F_{j,\tau}\Delta \ln Y_{\tau+1}$ for several alternative horizons. However, we cannot observe $F_{j,\tau}\Delta X_\tau^i$ directly. We thus use j's forecasts of the yen-dollar exchange rate and NY WTI crude oil futures for the

[5]The constant term can change over time when τ changes. But to the extent that τ is fixed, it is time invariant in each estimation.

proxies. Since only the forecasted level is available for these variables in *ESP Forecast*, we constructed their changes by taking logged difference between the forecasted future value and the realized current value.

The sample period of the forecast origin is from June 2011 to March 2018. We start the sample period from June 2011 to exclude discontinuous changes in *ESP Forecast* caused by the CPI base year revision. The sample period allows us to see whether there was a structural change after the BOJ introduced the explicit 2% inflation target in January 2013.

As we explained in section 3, *ESP Forecast* provides a panel of fixed event forecasts at various horizons. It is, however, important to stress that the quoted forecast monotonically diverges from the long-run anchor point towards actual value as the forecast horizon shortens. In particular, when the value in fiscal year $T-1$ is forecasted from January to May in year T, most of their components have already been realized and observed. Even when the value in fiscal years $T-1$ is forecasted from June to December in year T, some of their components have already been observed. Thus in the following analysis, we focus only on the following four types of forecasts.

The first type (denoted as "type L") is forecasts of the value in fiscal year $T+2$ which are quoted from June to December in year T. They have a desirable property to see the anchor of relatively long-term inflation forecasts in that their forecast horizons are the longest in *ESP Forecast.* But available variables are limited to real GDP growth rate and the Core CPI inflation rate. Therefore we cannot remove the effects of supply shocks in the first type when calculating the anchor, .

The second type (denoted as "type LM") is forecasts of the value in fiscal year $T+1$ which are quoted from January to May in year T. Their forecast horizons are slightly shorter than those in the first type but longer than the other two types. More importantly, the second type includes forecasted values of various macro variables, especially the yen-dollar exchange rate and oil price. We can see the anchor of long to medium term inflation forecasts after controlling for the effects of supply shocks in the second type.

The third type (denoted as "type MS") is forecasts of the value in fiscal year $T+1$ which are quoted from June to December in year T. Since the third type also includes forecasted values of various macro variables, we can see the anchor after controlling for the effects of supply shocks. However, since their forecast horizons are shorter, the anchor is likely to be that of medium to short term inflation forecasts.

The fourth type (denoted as "type S") is forecasts of the value in fiscal year T which are quoted from January to May in year T. It also includes forecasted values of various macro variables. Since the forecast horizons are the shortest, forecast errors tend to be the smallest among the four types. We may interpret that the forecast value reflects short-term expectations, which should be different from a long-term anchor of expectations.

By comparing the estimated anchor of inflation expectations in the four types above, we can see the difference of the properties between the long-run and short-run inflation expectations.

3.5.2 The Estimation Results

Table 3.4 to 3.7 and 3.8 to 3.10 summarize the estimation results with and without the proxy variables for supply shocks in the case with the four alternative types of the forecasts, respectively. Since *ESP Forecast* is the “fixed-event” type forecast data, forecasts made during different months have different horizons. Even though our division of data into the four types can partly mitigate the seasonal effects, it is possible that the effects contaminate our estimation in unexpected way. For the robustness check, the tables also report the results of the estimation with controling for the seasonal effects by introducing the horizon dummies into our regressions.

The estimated coefficient on the GDP growth rate forecast is positive in all cases and statistically significant in almost all cases. This implies that *ESP Forecast* data supports our assumption that the forecasters use the expectation-augmented Phillips curve such as (3.1) to form their expectations. As the tables show, the estimated coefficient on GDP growth forecast tends to be larger when the forecast origin is in the QQE period than when it is in the pre-QQE period. In particular, in the pre-QQE period, the estimated coefficient is around 0.2 in most cases and never exceed 0.3. In contrast, in the QQE period, the estimated coefficient frequently exceeds 0.4 and rarely falls below 0.2. These results indicate that the BOJ’s unprecedented monetary easing made the inflation forecast more sensitive to the GDP growth forecast and the slope of our Phillips curve steeper.

The result that the slope of Phillips curve becomes steeper is in stark contrast to the literature which reports flattening Phillips curve in Japan such as De Veirman [17], Fuhrer et al. [24], and Kaihatsu et al. [38]. Here it is important to stress that their results are based on the data in pre-QQE period. In particular, De Veirman [17] uses the data over 1971-2004, Fuhrer et al. [24] 1971-2009, and Kaihatsu et al. [38] over 1982-2012. To capture the clear picture, Figure 3.1 shows the changes of estimated slope of the Phillips curve using the all sample periods: January 2005 to March 2018 for the type LM, MS, and S forecasts.[6] The values in the figure are based on the estimation including the proxy for supply shocks. As the figure shows, the slope of the Phillips curve shows only modest change before the QQE period, which is consisten with the result by Kaihatsu et al. [38]. After the introduction of QQE, it jumps up in the case with the type LM and MS forecasts. It is interesting that in the case with the type S forecasts, which includes relatively short horizons forecast, the change of the slope coefficients is more gradual than the other two types.

In addition to the result above, Table 3.4 to 3.7 (without supply shock controls) and 3.8 to 3.10 (with supply shock controls) also show that the estimated constant term has been changed over time. In the table, the estimated constant term has three features depending on the forecast origin. First, they are negative in most cases when the forecast origin is before announcing the 2% inflation target. Second, they become significantly positive and sometimes took large positive values when the forecast origin is after the introduction of the 2% inflation target. Third it starts to decline in more recent years. Comparing the results with and without supply shock controls in the periods soon after the introduction of QQE, the estimated constant term in the former is basically greater than that in the latter. This implies that yen's depreciation and oil price increases are one of the reasons why our Phillips curve shifts upward in the QQE period. However, even if we control for the effects of these supply shock effects, we can still observe that the constant terms increase significantly soon after the QQE introduction and declines as the QQE regime continues.

We can observe some interesting features about the estimated constant terms with comparing the three types of forecasts in the case with supply shock controls. First,

[6] There does not exist the type L forecast data before April 2013.

the constant terms in the LM type tend to be higher than those in the other two types. Second, the timing of decline of the constant terms is different between the LM and other two types. In particular, it is only after the forecast origin is in 2017 when the estimated constant term starts to decline. In contrast, those in the MS and S types start to decline earlier as the QQE progressed. As explained in the previous section, forecasts in the LM types are those with relatively long time horizons, while forecasts in the MS and S types are those with shorter time horizons. The results thus imply that the structural changes in the constant term are different in their magnitude and timing depending on the length of forecast time horizons.

3.5.3 The Estimated Anchor of the Inflation Expectation

One of the key features in our expectations-augmented Phillips curve is that the constant term equals to the sum of the three components: the anchor of inflation expectations $\Pi^e_{\tau+1}$, the change in the potential output $-\alpha\Delta \ln Y^*_t$, and the realized output gap term $\alpha(\ln Y_\tau - \ln Y^*_\tau)$. Then we can derive the anchor of inflation expectations adding the value of $\hat{\alpha}\Delta \ln Y^*_t$ and subtracting $\hat{\alpha}(\ln Y_\tau - \ln Y^*_\tau)$ from the estimated constant term, where $\hat{\alpha}$ is the estimated coefficient on the GDP growth rate forecast.

Figure 3.2 and 3.3 depicted the change of derived anchor of inflation expectations over time for the four types of forecasts without and with supply shock controls, respectively. In deriving the anchor of inflation expectations, we used the estimation of output gap and potential growth rate in Japan published by *Cabinet Office, the government of Japan* after smoothing the effect of consumption tax increase in 2014.

The figures show some noteworthy features about the anchor of inflation expectations. First, the derived anchor is less than zero in almost all cases when the forecast origin is in 2011 and 2012. This implies that inflation expectations had been anchored in negative values before the BOJ announced 2% target in January 2013. As shown in Figure 1.1 in Chpter 1, after the GFC, the CPI inflation rates had been negative in Japan in most of the periods until May 2013. It is likely that the persistent CPI declines occurred not only because of prolonged recessions but partly due to the anchor of negative inflation expectations.

Second, the derived anchor increases significantly in 2013 and in 2014 and remained positive until 2018. This implies that the announcement of 2% target was at least successful in shifting the anchor of inflation expectations in positive values. Since the previous targeted rate was around 1%, the announcement of the 2% target was a dramatic change in the BOJ's commitment. In particular, when introducing the QQE on April 2013, the BOJ made a commitment that it would achieve the CPI price stability target of 2 percent "at the earliest possible time." It is likely that the dramatic change in the BOJ's policy regime changed inflation expectations upward.

Third, despite the upward shift after the announcement of 2% target, the derived anchor never reaches 2 percent. It never exceeds 1.5% in the case we control the effects of supply shocks. It exceeds 1.5% in 2015 for type L forecasts and in 2016 for type LM forecasts when we do not control the effects of supply shocks. But even in these cases, the increased anchor does not persist. This implies that the announcement of 2% target was not fully successful in anchoring inflation expectations at the targeted rate. As pointed out above, after introducing of 2% target, the CPI inflation rate turned into positive in Japan and started to decline in the latter half of 2014. It is likely that the role of the explicit inflation target faced structural changes in anchoring inflation expectations in Japan when it turned out that the 2% target would not be feasible in the short-run.

Comparing the four types of the estimated anchor, the derived anchors in types MS and S reach its peak earlier than the other two types. However, at the same time, the timing of decline is also earlier compared to the other types. In both with and without supply controls cases, the type MS and S anchor reach its peak in 2014 but start to decline soon after that. On the other hand, it is not until 2016 that the medium to long term type L or LM anchor start to decline. This implies that short-term anchor of inflation expectations is more sensitive to the change of environmet surrounding inflation in Japan. Soon after the the announcement of 2% target and start of the QQE policy, the short term anchor jumps up to the positive level with the expectation of its effect of increasing inflation. However, in response to the weak reaction and still decline of inflation rate started in 2014, it quickly reflects these conditions and starts to decline. In contrast, the derived anchor in type L and LM forecasts shows slower response and still continues to increase after the anchor in types MS and S forecasts already peaked. The medium-term anchor of inflation expectations shows delayed but larger fluctuations than the short-term anchor after the 2% target announcement. However, even with medium to long forecast horizons, the increases in the anchor of inflation expectations do not persist. The derived anchor in type L and LM starts to decline in 2016 at the latest and fell in the level around 1% in recent years.

In this way, the expectation anchor of inflation with different length of forecast horizons seem to have different properties about the speed of adjustment. On the other hand, there is also a common feature among them. After the end of 2016, all types of estimated anchor move back to the level slightly lower than 1%. As pointed out above, the slope of our Phillips curve seems to be steeper in recent years. Our results here imply that the main cause of weak forecast for future inflation, which is significantly lower than the target 2% in *ESP Forecast*, is mainly due to the decaying of the inflation targeting effect to raise the anchor of inflation expectations.

3.6 Robustness checks

In this section, we report the results of some robustness checks, which include omitting the forecasters drop out from the survey in the sample period, adding the other control variables, IV estimation, using unemployment gap instead of output gap, considering hybrid Phillips curve.

3.6.1 Omitting dropout

As a matter of empirical research using the survey data, repondents dropout can be the problem. If there are many forecasters who drop out or enter the survey in the middle of the sample period, it can be the source of some bias. Fortunately, in our data, a forecaster id is uniquely assigned to each forecaster, so we can follow the same forecaster and check when he or she enters and leave the survey. Here we pick up 29 forecasters who complete the survey and do the same regressions using the balanced panel data. The results are summerized in Table 3.11 to 3.11 (without supply shock controls) and 3.15 to 3.17 (with supply shock controls). The result is quantitatively and qualitatively similar to the benchmark case.

3.6.2 Adding US and China GDP growth rate

In the benchmark regression, we have derived the anchor of inflation expectations using forecasts of the yen-dollar exchange rate and the NY WTI crude oil futures price as supply shocks. The reason we use them is that both foreign exchange rates and oil prices have been major sources of supply shocks in the Japanese economy. However, in integrated global production networks, the Japanese economy is increasingly more connected with the rest of the world, especially with the USA and China. The purpose of the exercise here is to examine whether our results are robust even if we include forecasted growth rates of the USA and China as additional exogenous shocks. In the estimation, we take the difference between the forecasted and the realized values of the US and China's growth rates respectively to calculate the additional exogenous shocks. Putting aside including two additional explanatory variables, the estimated equation is the same as those in the benchmark case.

Table 3.18 to 3.20 report the estimation results with and without monthly time dummies for types LM, MS, and S of forecasts. The coefficients on the additional control variables frequently take significantly positive sign. This implies that accelerated growth in the USA and China had positive spillover effects on the inflation rate in Japan. Compared with those in the benchmark case, the constant term becomes insignificant in 2014 for type LM forecasts, in 2016 for type MS forecasts, and in 2017 for type S forecasts. However, most of the estimated coefficients remain statistically significant and are essentially the same as the benchmark case.

The estimated coefficient of the GDP growth rate forecast is significantly positive in all cases but become larger in the QQE period than in the pre-QQE period. More importantly, the estimated constant term changes over time. It is negative in most cases before announcing the 2% target. However, it becomes significantly positive after announcing the 2% target and then starts to decline around 2016.

Based on the estimated results without monthly time dummies in the Table 3.18 to 3.20, we derive the anchor of inflation expectations for the four types of forecasts using the same method in the benchmark case. Figure 3.4 depicts how the derived anchors of inflation expectations changed over time when excluding the effects of the supply shocks and the two exogenous shocks. Compared with those in Figure 3.3, the derived anchor in the figure is slightly larger for type LM forecasts and slightly smaller for type MS and S forecasts. However, their features are essentially the same. The announcement of 2% target is successful in anchoring inflation expectations in positive values but not fully successful in anchoring them at the targeted rate.

3.6.3 IV estimation

To deal with the possibility of endogeneity problem which will be caused by the correlation between the output growth $F_{j,\tau}\Delta \ln Y_{\tau+1}$ in the explanatory variables and the error term $\varepsilon_{j,\tau}$, we here utilize one-month lagged forecast of output growth, oil price, and exchange rate as the instrument to $F_{j,\tau}\Delta \ln Y_{\tau+1}$.[7] The estimation results are summerized in the Table 3.21 to 3.24 and 3.25 to 3.27 without and with supply controls, respectively.

As in the previous sections, the estimations are implemented either with or without monthly time dummies. Because of limited availability of instrumental variables, the number of observations becomes smaller. The constant term becomes insignificant in

[7] In case of type L forecasts, we use only one-month lagged values of the GDP growth rate forecasts as an instrumental variable because the yen-dollar exchange forecasts and the crude oil futures price forecasts are not available.

2012 for type LM forecasts and in 2018 for type S forecasts. However, most of the estimated coefficients remain statistically significant and are essentially the same as in the benchmark case even if we estimate by using the instrumental variables.

The estimated coefficient of the GDP growth rate forecast is positive in all cases but became larger in the QQE period than in the pre-QQE period. More importantly, the estimated constant term becomes significantly positive after announcing the 2% target and then starts to decline around 2015. This indicates that the BOJ's unprecedented monetary easing shifted our panel Phillips curve upward for a few years but that the upward shift did not persist when it turned out that the 2% target would not be feasible in the short-run.

Based on the estimated results without monthly time dummies in Table 3.21 to 3.24 and 3.25, we derived the anchor of inflation expectations Π_t^e for the four types of forecasts using the same method in the benchmark case. Figure 3.5 and 3.6 depict how the derived anchors of inflation expectations changes over time with and without supply controls, respectively. Although some slight differences exist, they are essentially the same as those in Figure 3.2 and 3.3. That is, the derived anchor, which tends to be negative before announcing the 2% target, increases significantly in 2013 and in 2014 and remains positive in the following years. However, despite the upward shift, the derived anchor never reaches 2%. This implies that the announcement of 2% target was successful in anchoring inflation expectations in positive values but was not successful in anchoring them at the targeted rate.

3.6.4 Unemployment-gap Phillips Curve

We also consider the unemployment-gap version Phillips curve, which can be written as

$$\Pi_t = \Pi_t^e + \alpha(u_t - u_t^*) + U_t, \tag{3.6}$$

where u_t^* is the equilibrium unemployment rate. Defining the individual forecaster j's expectation operator based on information in time $t-1$ by $E_{j,t-1}$, we obtain

$$E_{j,t-1}\Pi_t = \Pi_t^e + \alpha E_{j,t-1}(u_t - u^*) + E_{j,t-1}U_t \tag{3.7}$$

and then our regression equation becomes

$$F_{j,\tau}\Pi_{T+1} = \textit{constant term} + \alpha F_{j,\tau}(u_{T+1} - u_{T+1}^*) + \sum_{i=1}^{N} \beta_\tau^i F_{j,\tau}\Delta X_T^i + \varepsilon_{j,\tau}. \tag{3.8}$$

To estimate the above equation, we need the forecast data for the future equilibrium unemployment, u_{T+1}^*. As the proxy for this variable, we use the forecast for the NAIRU in Japan reported in the *OECD Economic Outlook*. The estimation results are summerized in the Table 3.28 to 3.30 (without supply controls) and 3.31 to 3.31 (with supply controls). As the tables show, about the type LM, the results are basically the same as the benchmark case. In particular, the slope of phillips curve becomes steeper and the constant term becomes larger after the introduction of QQE. This implies that at least about the long to medium inflation expectations, not only the relationship between output and inflation but also that of unemployment and inflation has recovered in recent period in Japan. In contrast, about the type MS and S, the coefficient on the unemployment gap is not significant in recent years. The results here may suggest that the forecasters consider the forecasting power of unemployment for relatively short term inflation is not so storong as before.

3.6.5 Hybrid Phillips Curve

As the final robustness check, we consider the model based on the hybrid Phillips curve, which explicitly tries to capture the dependance of current inflation on the past inflation rate. In particular, we estimate the following equation:

$$F_{j,\tau}\Pi_{\tau+1} = \textit{constant term} + \gamma F_{j,\tau}\Pi_{\tau} + \alpha F_{j,\tau}\Delta \ln Y_{\tau+1} + \sum_{i=1}^{N} \beta_{\tau}^{i} F_{j,\tau}\Delta X_{\tau}^{i} + \varepsilon_{j,\tau}. \quad (3.9)$$

To estimate this equation, we need the forecast data for inflation rate in the current and next fiscal year forecasted in the same period. As explained above, type L forecast data contains the inflation forecasts in the fiscal year $T+2$ which are quoted from June to December in year T. At the same timing, the forecasters also answer the inflation forecasts in the fiscal year $T+1$ and they are categorized as type MS data. By utilizing type L data for $F_{j,\tau}\Pi_{\tau+1}$ and type MS data for $F_{j,\tau}\Pi_{\tau}$, we can estimate (3.9). In a similar fashion, we can also use type LM data for $F_{j,\tau}\Pi_{\tau+1}$ and type S data for $F_{j,\tau}\Pi_{\tau}$, both of which are answered in January to May in the period T.

Table 3.34 to 3.35 and 3.36 report the result with and without supply controls, respectively. In all cases, the estimated constant term is slightly smaller compared to the benchmark case and insignificant in 2012 for type LM forecasts with supply controls. In 2017 and 2018, the estimated constant becomes negative, which is not observed in the exercises so far. Nevertheless, the time change of the constant term is essentially the same as in the benchmark case. Soon after the introduction of QQE policy, it becomes significantly positive and increases until 2016, but starts to decline in more recent years. As in the benchmark case, the estimated coefficient of the GDP growth rate forecast becomes larger in the QQE period than in the pre-QQE period, even though the level is slightly lower.

The estimated coefficient on the current year inflation forecast is significant in all cases and the value is above 0.5 in most cases and especially high in 2014, 2017 and 2018. In the *Comprehensive Assessment* of QQE policy in September 2016, the BOJ argued that the one of the main reason why the inflation target of 2% had not been achieved at the time could be the strong backward-looking expectations formation by the private agents in Japan. Our results here at least partially support this conjecture.

3.7 Conclusion

In this chapter, we explored whether the explicit inflation targeting regime could anchor inflation expectations in Japan. In the analysis, we estimated cross-section Phillips curves by using Japanese forecaster-level data of "*ESP Forecast*". We found significant structural changes in how to form private inflation forecasts. Before the BOJ announced the 2% inflation target, inflation expectations had been anchored in negative values, which caused prolonged deflation after the GFC. But the new target increased the estimated anchor of inflation expectations to positive values. This implies that the 2% inflation target was successful in overcoming prolonged deflation through raising the anchor of inflation expectations.

However, the estimated anchor has never reached the target. More importantly it declined around 2015 when it turned out that the 2% inflation target would not be feasible in the short-run. This implies that an explicit inflation targeting needs to be a feasible one to anchor inflation expectations persistently.

Date	Description		Governor
19-Dec-08	Lowering of the Bank's target for the uncollateralized overnight call rate		Shirakawa
	by 20 basis points; it will be encouraged to remain at around 0.1 percent.		
18-Dec-09	The midpoints of most Policy Board members' "understanding" are around		Shirakawa
	1 percent CPI inflation rate.		
5-Oct-10	Comprehensive Monetary Easing		Shirakawa
22-Jan-13	The "2% Price Stability Target" under the Framework for the Conduct of		Shirakawa
	Monetary Policy		
4-Apr-13	Introduction of the "Quantitative and Qualitative Monetary	QQE1	Kuroda
	Easing (QQE)"		
31-Oct-14	Expansion of the Quantitative and Qualitative Monetary Easing	QQE2	Kuroda
29-Jan-16	Introduction of "Quantitative and Qualitative Monetary Easing with a Negative Interest Rate"	NIRP1	Kuroda
21-Sep-16	New Framework for Strengthening Monetary Easing: "Quantitative and Qualitative Monetary Easing with Yield Curve Control"	NIRP2	Kuroda

Table 3.1: Timeline of Japan's Unconventional Monetary Policy

forecast origin	Estimated fiscal year T								
	FY2011	FY2012	FY2013	FY2014	FY2015	FY2016	FY2017	FY2018	FY2019
April in T−2	NA	NA	NA	NA	1.9	2.1	1.9	1.9	1.9
July in T−2	NA	NA	NA	NA	1.9	2.1	1.8	1.9	1.8
Oct. in T−2	−0.4	0.6	0.5	0.8	1.9	2.1	1.8	1.7	1.8
Jan. in T−1	−0.2	0.6	0.5	0.9	1.9	2.2	1.8	1.7	1.8
April in T−1	0.1	0.7	0.7	1.4	1.9	2	1.7	1.7	NA
July in T−1	0.1	0.7	0.7	1.3	1.9	1.9	1.7	1.5	NA
Oct. in T−1	0.1	0.1	0.4	1.3	1.7	1.4	1.5	1.4	NA
Jan. in T	0.3	0.1	0.4	1.3	1	0.8	1.5	1.4	NA
April in T	0.7	0.3	0.7	1.3	0.8	0.5	1.4	NA	NA
July in T	0.7	0.2	0.6	1.3	0.7	0.1	1.1	NA	NA
Oct. in T	0	−0.1	0.7	1.2	0.1	−0.1	0.8	NA	NA
Jan. in T+1	−0.1	−0.2	0.7	0.9	0.1	−0.2	0.8	NA	NA
April in T+1	0	−0.2	0.8	0.8	0	−0.3	NA	NA	NA

Table 3.2: The BOJ's Point Estimates of Core CPI Inflation Rates

real GDP growth rate

		Jan. in T−1	July in T−1	Jan. in T	July in T	Jan. in T+1
FY2005	average		1.63	1.06	1.44	2.82
	standard deviation		0.41	0.40	0.49	0.20
FY2006	average	1.95	1.69	2.12	2.71	1.89
	standard deviation	0.35	0.49	0.52	0.30	0.16
FY2007	average	2.14	2.07	1.92	2.29	1.36
	standard deviation	0.40	0.46	0.38	0.27	0.17
FY2008	average	2.32	2.30	1.92	1.33	−1.31
	standard deviation	0.43	0.37	0.32	0.28	0.48
FY2009	average	2.03	1.62	−1.23	−3.61	−2.76
	standard deviation	0.36	0.33	0.90	0.58	0.18
FY2010	average	1.21	1.11	1.25	2.47	3.22
	standard deviation	0.52	0.61	0.39	0.33	0.18
FY2011	average	1.65	1.81	1.39	0.17	−0.33
	standard deviation	0.38	0.43	0.33	0.40	0.27
FY2012	average	2.06	2.92	1.89	2.32	0.99
	standard deviation	0.30	0.35	0.43	0.22	0.15
FY2013	average	1.42	1.59	1.61	2.75	2.53
	standard deviation	0.51	0.39	0.43	0.25	0.12
FY2014	average	0.23	0.58	0.84	0.85	−0.60
	standard deviation	0.56	0.48	0.35	0.31	0.15
FY2015	average	1.35	1.35	1.75	1.66	1.05
	standard deviation	0.32	0.28	0.36	0.24	0.11
FY2016	average	1.63	1.73	1.44	0.62	1.21
	standard deviation	0.38	0.30	0.26	0.26	0.10
FY2017	average	0.06	0.84	1.12	1.40	1.88
	standard deviation	0.31	0.30	0.24	0.16	0.11
FY2018	average	1.02	1.10	1.26	NA	NA
	standard deviation	0.36	0.28	0.22	NA	NA
FY2019	average	0.77	NA	NA	NA	NA
	standard deviation	0.25	NA	NA	NA	NA

Core CPI inflation rate

		Jan. in T−1	July in T−1	Jan. in T	July in T	Jan. in T+1
FY2005	average		0.00	−0.11	−0.10	0.02
	standard deviation		0.19	0.15	0.13	0.09
FY2006	average	0.12	0.18	0.29	0.56	0.20
	standard deviation	0.27	0.20	0.15	0.13	0.03
FY2007	average	0.53	0.68	0.36	0.06	0.13
	standard deviation	0.22	0.22	0.14	0.09	0.06
FY2008	average	0.67	0.48	0.39	1.44	1.32
	standard deviation	0.18	0.17	0.13	0.32	0.10
FY2009	average	0.56	0.84	−0.58	−1.37	−1.54
	standard deviation	0.27	0.36	0.33	0.25	0.09
FY2010	average	0.19	−0.51	−0.93	−0.92	−0.85
	standard deviation	0.41	0.43	0.32	0.18	0.08
FY2011	average	−0.31	−0.05	−0.18	0.50	−0.10
	standard deviation	0.32	0.20	0.19	0.22	0.09
FY2012	average	0.14	0.33	−0.20	0.06	−0.15
	standard deviation	0.27	0.29	0.26	0.14	0.07
FY2013	average	0.14	0.20	0.10	0.36	0.72
	standard deviation	0.26	0.21	0.25	0.14	0.09
FY2014	average	2.34	2.71	0.88	1.12	0.95
	standard deviation	0.38	0.32	0.30	0.17	0.08
FY2015	average	0.97	1.79	0.84	0.33	0.11
	standard deviation	0.41	0.38	0.33	0.22	0.07
FY2016	average	1.27	1.22	0.82	0.03	−0.25
	standard deviation	0.48	0.41	0.33	0.24	0.06
FY2017	average	1.13	0.72	0.77	0.70	0.66
	standard deviation	0.35	0.42	0.24	0.15	0.08
FY2018	average	0.99	0.89	0.88	NA	NA
	standard deviation	0.35	0.31	0.28	NA	NA
FY2019	average	0.90	NA	NA	NA	NA
	standard deviation	0.40	NA	NA	NA	NA

Table 3.3: The Basic statistics of forecasted values in *ESP Forecast*

3.8 Tables (Benchmark case, without supply shock controls)

Type L										
	2013 06-12		2014 06-12		2015 06-12		2016 06-12		2017 06-12	
VARIABLES										
gdp growth	0.527***	0.527***	0.164	0.157	0.205***	0.199**	0.644***	0.643***	0.450***	0.455***
	(0.0523)	(0.0529)	(0.110)	(0.120)	(0.0755)	(0.0767)	(0.0413)	(0.0421)	(0.110)	(0.111)
Constant	0.287***	0.287***	1.094***	1.103***	1.227***	1.229***	0.344***	0.344***	0.678***	0.675***
	(0.0638)	(0.0646)	(0.151)	(0.165)	(0.0253)	(0.0259)	(0.0429)	(0.0437)	(0.0843)	(0.0844)
Observations	289	289	289	289	268	268	285	285	263	263
R-squared	0.253	0.257	0.019	0.020	0.044	0.054	0.452	0.455	0.093	0.100
Horizon dummy		YES		YES		YES		YES		YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3.4: Benchmark case without supply shock controls, Type L

Type LM																
	2011 01-05		2012 01-05		2013 01-05		2014 01-05		2015 01-05		2016 01-05		2017 01-05		2018 01-03	
VARIABLES																
gdp growth	0.139***	0.147**	0.250***	0.253***	0.194***	0.178***	0.524***	0.526***	0.353***	0.363***	0.535***	0.518***	0.538***	0.541***	0.729***	0.729***
	(0.0424)	(0.0607)	(0.0549)	(0.0547)	(0.0501)	(0.0489)	(0.0668)	(0.0671)	(0.105)	(0.105)	(0.0884)	(0.0849)	(0.0647)	(0.0651)	(0.134)	(0.137)
Constant	-0.0715*	-0.0887	-0.239***	-0.245***	0.410***	0.414***	0.304***	0.301***	0.655***	0.639***	0.955***	0.961***	0.426***	0.423***	0.345***	0.345***
	(0.0361)	(0.139)	(0.0796)	(0.0791)	(0.0294)	(0.0286)	(0.0910)	(0.0913)	(0.188)	(0.188)	(0.0247)	(0.0240)	(0.0696)	(0.0700)	(0.101)	(0.102)
Observations	219	219	210	210	209	209	215	215	215	215	215	215	207	207	119	119
R-squared	0.064	0.099	0.164	0.188	0.083	0.127	0.219	0.225	0.085	0.092	0.223	0.281	0.310	0.312	0.229	0.229
Horizon dummy		YES		YES		YES		YES		YES		YES		YES		YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3.5: Benchmark case without supply controls, Type LM

Type MS														
	2011 06-12		2012 06-12		2013 06-12		2014 06-12		2015 06-12		2016 06-12		2017 06-12	
VARIABLES														
gdp growth	0.233***	0.237***	0.273***	0.271***	0.406***	0.419***	0.478***	0.569***	0.603***	0.538***	0.452***	0.476***	0.488***	0.514***
	(0.0323)	(0.0425)	(0.0298)	(0.0318)	(0.0624)	(0.0689)	(0.0615)	(0.0610)	(0.0731)	(0.0781)	(0.0626)	(0.0622)	(0.0779)	(0.0776)
Constant	-1.054***	-0.562***	-0.273***	-0.271***	0.501***	0.492***	0.456***	0.328***	0.178**	0.186	0.267***	0.245***	0.302***	0.272***
	(0.0805)	(0.107)	(0.0476)	(0.0509)	(0.0334)	(0.0367)	(0.0877)	(0.0890)	(0.0823)	(0.134)	(0.0619)	(0.0604)	(0.0837)	(0.0836)
Observations	316	316	306	306	311	311	319	319	311	311	317	317	291	291
R-squared	0.378	0.538	0.226	0.253	0.205	0.213	0.207	0.262	0.205	0.239	0.182	0.239	0.179	0.206
Horizon dummy		YES		YES		YES		YES		YES		YES		YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3.6: Benchmark case without supply controls, Type MS

Type LM

	2011 01-05		2012 01-05		2013 01-05		2014 01-05		2015 01-05		2016 01-05		2017 01-05		2018 01-03	
VARIABLES																
gdp growth	0.139***	0.147**	0.250***	0.253***	0.194***	0.178***	0.524***	0.526***	0.353***	0.363***	0.535***	0.518***	0.538***	0.541***	0.729***	0.729***
	(0.0424)	(0.0607)	(0.0549)	(0.0547)	(0.0501)	(0.0489)	(0.0668)	(0.0671)	(0.105)	(0.105)	(0.0884)	(0.0849)	(0.0647)	(0.0651)	(0.134)	(0.137)
Constant	-0.0715*	-0.0887	-0.239***	-0.245***	0.410***	0.414***	0.304***	0.301***	0.655***	0.639***	0.955***	0.961***	0.426***	0.423***	0.345***	0.345***
	(0.0361)	(0.139)	(0.0796)	(0.0791)	(0.0294)	(0.0286)	(0.0910)	(0.0913)	(0.188)	(0.188)	(0.0247)	(0.0240)	(0.0696)	(0.0700)	(0.101)	(0.102)
Observations	219	219	210	210	209	209	215	215	215	215	215	215	207	207	119	119
R-squared	0.064	0.099	0.164	0.188	0.083	0.127	0.219	0.225	0.085	0.092	0.223	0.281	0.310	0.312	0.229	0.229
Horizon dummy		YES		YES		YES		YES		YES		YES		YES		YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3.7: Benchmark case without supply controls, Type S

3.9 Tables (Benchmark case, with supply shock controls)

Type LM																
	2011 01-05		2012 01-05		2013 01-05		2014 01-05		2015 01-05		2016 01-05		2017 01-05		2018 01-03	
VARIABLES																
gdp growth	0.0693**	0.0753	0.202***	0.203***	0.184***	0.171***	0.488***	0.492***	0.335***	0.346***	0.428***	0.401***	0.476***	0.477***	0.732***	0.731***
	(0.0321)	(0.0719)	(0.0595)	(0.0592)	(0.0488)	(0.0478)	(0.0640)	(0.0651)	(0.108)	(0.106)	(0.0993)	(0.0967)	(0.0777)	(0.0789)	(0.124)	(0.125)
NY WTI Oil	-0.717	-0.569	0.124	0.156	0.286	0.221	2.197***	4.300***	1.869***	1.994***	1.161***	1.331***	0.976***	0.982***	1.685***	1.764***
	(0.494)	(0.509)	(0.438)	(0.431)	(0.517)	(0.512)	(0.591)	(0.595)	(0.579)	(0.564)	(0.420)	(0.431)	(0.336)	(0.343)	(0.529)	(0.544)
USD/Yen rate	-0.333	-0.289	-0.0438	-0.0243	0.121	-0.0930	2.962**	2.772**	2.319	2.210	-0.903	0.115	-1.462	-1.439**	1.835	1.647
	(0.639)	(0.644)	(0.615)	(0.642)	(0.897)	(0.889)	(1.186)	(1.172)	(1.777)	(1.735)	(1.055)	(1.088)	(0.945)	(0.651)	(1.311)	(1.334)
Constant	0.130*	0.110	-0.155**	-0.158*	0.395***	0.404***	0.243***	0.240***	0.411**	0.382**	0.777***	0.746***	0.430***	0.429***	0.342***	0.342***
	(0.0780)	(0.175)	(0.0740)	(0.0933)	(0.0340)	(0.0351)	(0.0853)	(0.0873)	(0.192)	(0.182)	(0.0727)	(0.0718)	(0.0753)	(0.0760)	(0.0933)	(0.0937)
Observations	160	160	158	158	163	163	162	162	167	167	169	169	188	188	114	114
R-squared	0.043	0.068	0.123	0.142	0.087	0.118	0.365	0.380	0.154	0.161	0.238	0.301	0.353	0.354	0.361	0.367
Horizon dummy		YES		YES		YES		YES		YES		YES		YES		YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.8: Benchmark case with supply controls, Type LM

Type MS

	2011 06-12		2012 06-12		2013 06-12		2014 06-12		2015 06-12		2016 06-12		2017 06-12	
VARIABLES														
gdp growth	0.293***	0.244***	0.238***	0.229***	0.432***	0.447***	0.470***	0.485***	0.454***	0.422***	0.332***	0.366***	0.401***	0.424***
	(0.0388)	(0.0510)	(0.0363)	(0.0385)	(0.0726)	(0.0807)	(0.0712)	(0.0759)	(0.0747)	(0.0798)	(0.0664)	(0.0640)	(0.0884)	(0.0878)
NY WTI Oil	0.852**	0.436	0.833***	0.843***	1.472***	1.367**	1.834***	1.833***	0.879***	0.585	1.110***	1.198***	2.171***	2.308***
	(0.373)	(0.332)	(0.191)	(0.209)	(0.491)	(0.531)	(0.336)	(0.471)	(0.332)	(0.363)	(0.262)	(0.258)	(0.321)	(0.321)
USD/Yen rate	0.970	0.437	-1.72	-1.677***	1.932***	1.956***	1.799**	1.713**	-1.026	-0.838	2.659***	3.224***	1.505***	1.591***
	(0.588)	(0.544)	(1.448)	(0.461)	(0.723)	(0.741)	(0.808)	(0.829)	(1.182)	(1.190)	(0.637)	(0.750)	(0.519)	(0.526)
Constant	-0.964***	-0.577***	-0.179***	-0.168***	0.386***	0.377***	0.455***	0.436***	0.271**	0.345**	0.162**	0.106	0.275***	0.241***
	(0.0937)	(0.128)	(0.0584)	(0.0623)	(0.0473)	(0.0505)	(0.102)	(0.111)	(0.118)	(0.135)	(0.0710)	(0.0728)	(0.0898)	(0.0901)
Observations	239	239	232	232	238	238	240	240	257	257	261	261	285	285
R-squared	0.390	0.494	0.258	0.294	0.223	0.232	0.276	0.284	0.177	0.192	0.247	0.307	0.338	0.370
Horizon dummy		YES		YES		YES		YES		YES		YES		YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.9: Benchmark case with supply controls, Type MS

Type S

VARIABLES	2011 01-05		2012 01-05		2013 01-05		2014 01-05		2015 01-05		2016 01-05		2017 01-05		2018 01-03	
gdp growth	0.161***	0.0862**	0.127***	0.187***	0.144***	0.142**	0.143**	0.167**	0.184***	0.148**	0.206***	0.177**	0.313***	0.338***	0.548***	0.552***
	(0.0309)	(0.0398)	(0.0649)	(0.0633)	(0.0549)	(0.0600)	(0.0684)	(0.0696)	(0.0656)	(0.0636)	(0.0775)	(0.0781)	(0.0622)	(0.0692)	(0.128)	(0.131)
NY WTI Oil	0.535	1.369***	0.823***	0.577**	0.765***	0.763***	0.584	0.607	1.752***	1.462***	0.874***	0.708***	0.952***	0.941***	0.868***	0.736**
	(0.367)	(0.462)	(0.216)	(0.226)	(0.249)	(0.262)	(0.385)	(0.393)	(0.199)	(0.238)	(0.192)	(0.246)	(0.338)	(0.340)	(0.304)	(0.321)
USD/Yen rate	0.109	0.0922	1.730**	1.358*	0.802**	0.806	2.014***	2.146***	1.067	0.549	2.387***	0.746	0.980**	0.887**	0.732	1.103
	(0.465)	(0.405)	(0.707)	(0.729)	(0.359)	(0.502)	(0.660)	(0.657)	(0.963)	(0.872)	(0.500)	(0.737)	(0.421)	(0.413)	(0.700)	(0.749)
Constant	-0.191**	-0.146*	-0.604***	-0.513***	-0.197**	-0.193	0.733***	0.707***	0.454***	0.674***	0.343***	0.315***	0.266***	0.240**	0.125***	0.128
	(0.0777)	(0.0739)	(0.119)	(0.116)	(0.0896)	(0.118)	(0.0553)	(0.0560)	(0.149)	(0.167)	(0.105)	(0.108)	(0.0980)	(0.106)	(0.0601)	(0.163)
Observations	210	210	196	196	198	198	202	202	207	207	214	214	214	214	122	122
R-squared	0.326	0.454	0.325	0.379	0.228	0.230	0.104	0.153	0.345	0.452	0.440	0.473	0.210	0.217	0.270	0.273
Horizon dummy		YES		YES		YES		YES		YES		YES		YES		YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.10: Benchmark case with supply controls, Type S

3.10 Tables (Omitting dropout, without supply shock controls)

Type L										
	2013 06-12		2014 06-12		2015 06-12		2016 06-12		2017 06-12	
VARIABLES										
gdp growth	0.532***	0.532***	0.147	0.135	0.225***	0.220***	0.677***	0.677***	0.468***	0.484***
	(0.0533)	(0.0533)	(0.124)	(0.134)	(0.0828)	(0.0840)	(0.0396)	(0.0402)	(0.131)	(0.131)
Constant	0.296***	0.296***	1.124***	1.140***	1.246***	1.247***	0.324***	0.324***	0.709***	0.699***
	(0.0668)	(0.0668)	(0.175)	(0.187)	(0.0293)	(0.0299)	(0.0424)	(0.0429)	(0.0956)	(0.0956)
Observations	203	203	203	203	203	203	203	203	203	203
R-squared	0.282	0.282	0.014	0.017	0.051	0.060	0.530	0.532	0.088	0.098
Horizon dummy		YES		YES		YES		YES		YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3.11: Omitting dropout without supply shock controls, Type L

Type LM																
	2011 01-05		2012 01-05		2013 01-05		2014 01-05		2015 01-05		2016 01-05		2017 01-05		2018 01-03	
VARIABLES																
gdp growth	0.186***	0.219***	0.197***	0.202***	0.188***	0.177***	0.482***	0.483***	0.219*	0.225*	0.533***	0.513***	0.547***	0.552***	0.675***	0.675***
	(0.0354)	(0.0509)	(0.0575)	(0.0578)	(0.0514)	(0.0509)	(0.0731)	(0.0738)	(0.125)	(0.125)	(0.0871)	(0.0839)	(0.0653)	(0.0654)	(0.149)	(0.151)
Constant	-0.161*	-0.239*	-0.155*	-0.164*	0.428***	0.432***	0.366***	0.365***	0.889***	0.879***	0.974***	0.982***	0.435***	0.430***	0.393***	0.394***
	(0.0888)	(0.122)	(0.0837)	(0.0839)	(0.0283)	(0.0277)	(0.102)	(0.103)	(0.226)	(0.226)	(0.0236)	(0.0225)	(0.0721)	(0.0726)	(0.112)	(0.114)
Observations	145	145	145	145	145	145	145	145	145	145	145	145	145	145	87	87
R-squared	0.099	0.139	0.106	0.133	0.107	0.152	0.217	0.221	0.032	0.037	0.285	0.354	0.351	0.355	0.177	0.177
Horizon dummy		YES		YES		YES		YES		YES		YES		YES		YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3.12: Omitting dropout without supply controls, Type LM

Type MS

	2011 06-12		2012 06-12		2013 06-12		2014 06-12		2015 06-12		2016 06-12		2017 06-12	
VARIABLES														
gdp growth	0.429***	0.213***	0.238***	0.234***	0.416***	0.434***	0.450***	0.537***	0.540***	0.481***	0.465***	0.493***	0.478***	0.497***
	(0.0337)	(0.0434)	(0.0280)	(0.0304)	(0.0678)	(0.0755)	(0.0648)	(0.0651)	(0.0743)	(0.0801)	(0.0617)	(0.0616)	(0.0774)	(0.0774)
Constant	-1.033***	-0.488***	-0.224***	-0.217***	0.503***	0.490***	0.496***	0.372***	0.225***	0.291**	0.272***	0.245***	0.333***	0.310***
	(0.0840)	(0.109)	(0.0453)	(0.0494)	(0.0364)	(0.0405)	(0.0948)	(0.0977)	(0.027)	(0.138)	(0.0604)	(0.0588)	(0.0828)	(0.0830)
Observations	203	203	203	203	203	203	203	203	203	203	203	203	203	203
R-squared	0.381	0.569	0.213	0.251	0.208	0.219	0.198	0.255	0.196	0.228	0.219	0.292	0.190	0.212
Horizon dummy		YES		YES		YES		YES		YES		YES		YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3.13: Omitting dropout without supply controls, Type MS

Type S																
	2011 01-05		2012 01-05		2013 01-05		2014 01-05		2015 01-05		2016 01-05		2017 01-05		2018 01-03	
VARIABLES																
gdp growth	0.113**	0.120**	0.240***	0.137***	0.192***	0.148***	0.207***	0.230***	0.236**	0.186**	0.560***	0.324***	0.423***	0.470***	0.502***	0.497***
	(0.0499)	(0.0465)	(0.0502)	(0.0501)	(0.0367)	(0.0549)	(0.0700)	(0.0711)	(0.0909)	(0.0825)	(0.0784)	(0.0837)	(0.0598)	(0.0655)	(0.132)	(0.135)
Constant	0.279***	0.0121	-0.585***	-0.384***	-0.202***	-0.109	0.795***	0.776***	0.0755	0.163	-0.225**	0.0419	0.287***	0.226***	0.291*	0.298*
	(0.0641)	(0.0549)	(0.0972)	(0.0961)	(0.0761)	(0.113)	(0.0493)	(0.0500)	(0.158)	(0.143)	(0.0900)	(0.0961)	(0.0737)	(0.0815)	(0.165)	(0.169)
Observations	145	145	145	145	145	145	145	145	145	145	145	145	145	145	87	87
R-squared	0.053	0.477	0.130	0.335	0.150	0.166	0.073	0.112	0.045	0.309	0.305	0.437	0.234	0.261	0.206	0.210
Horizon dummy		YES		YES		YES		YES		YES		YES		YES		YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3.14: Omitting dropout without supply controls, Type S

3.11 Tables (Omitting dropout, with supply shock controls)

Type LM

VARIABLES	2011 01-05		2012 01-05		2013 01-05		2014 01-05		2015 01-05		2016 01-05		2017 01-05		2018 01-03	
gdp growth	0.111***	0.131**	0.153**	0.153**	0.180***	0.169***	0.467***	0.468***	0.260*	0.267	0.428***	0.396***	0.501***	0.505***	0.642***	0.644***
	(0.0392)	(0.0578)	(0.0594)	(0.0599)	(0.0482)	(0.0477)	(0.0699)	(0.0716)	(0.141)	(0.116)	(0.0939)	(0.0919)	(0.0795)	(0.0798)	(0.143)	(0.143)
NY WTI Oil	-0.730	-0.624	-0.155	-0.0785	-0.339	-0.420	4.466***	4.489***	2.511***	2.635***	1.387***	1.576***	0.925***	0.927***	1.705***	1.787***
	(0.520)	(0.533)	(0.467)	(0.462)	(0.437)	(0.432)	(0.591)	(0.601)	(0.597)	(0.597)	(0.363)	(0.386)	(0.330)	(0.332)	(0.557)	(0.569)
USD/Yen rate	0.278	0.354	0.785	0.850	0.209	0.0405	4.006***	3.837***	1.501	1.434	-1.847*	-0.868	-0.790	-0.728	1.818	1.587
	(0.641)	(0.638)	(0.654)	(0.673)	(0.851)	(0.844)	(1.313)	(1.315)	(1.648)	(1.615)	(0.938)	(0.984)	(0.609)	(0.602)	(1.395)	(1.425)
Constant	-0.141*	-0.0232	-0.0971	-0.100	0.442***	0.450***	0.215**	0.219**	0.663***	0.640***	0.787***	0.755***	0.421***	0.417***	0.425***	0.423***
	(0.0799)	(0.148)	(0.0919)	(0.0919)	(0.0294)	(0.0302)	(0.106)	(0.109)	(0.215)	(0.205)	(0.0625)	(0.0651)	(0.0803)	(0.0807)	(0.110)	(0.109)
Observations	145	145	145	145	145	145	145	145	145	145	145	145	145	145	87	87
R-squared	0.061	0.088	0.064	0.091	0.120	0.147	0.402	0.411	0.167	0.177	0.359	0.416	0.385	0.387	0.325	0.333
Horizon dummy		YES		YES		YES		YES		YES		YES		YES		YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.15: Omitting dropout with supply controls, Type LM

Type MS														
	2011 06-12		2012 06-12		2013 06-12		2014 06-12		2015 06-12		2016 06-12		2017 06-12	
VARIABLES														
gdp growth	0.358***	0.185***	0.189***	0.169***	0.477***	0.501***	0.413***	0.415***	0.377***	0.349***	0.320***	0.354***	0.427***	0.443***
	(0.0404)	(0.0500)	(0.0368)	(0.0396)	(0.0819)	(0.0931)	(0.0766)	(0.0848)	(0.0746)	(0.0806)	(0.0658)	(0.0643)	(0.0888)	(0.0888)
NY WTI Oil	0.958***	0.495*	0.503***	0.486**	1.430**	1.314**	1.830***	1.904***	1.024***	0.775**	1.034***	1.093***	1.862***	1.978***
	(0.339)	(0.280)	(0.186)	(0.203)	(0.557)	(0.601)	(0.365)	(0.518)	(0.349)	(0.380)	(0.251)	(0.251)	(0.345)	(0.347)
USD/Yen rate	1.874***	1.132**	-0.683	-0.576	3.449***	3.693***	2.049**	1.872**	-1.632	-1.466	2.196***	2.658***	1.718***	1.808***
	(0.566)	(0.526)	(0.469)	(0.472)	(0.757)	(0.756)	(0.848)	(0.854)	(1.176)	(1.180)	(0.617)	(0.719)	(0.549)	(0.558)
Constant	-0.904***	-0.447***	-0.128**	-0.0998	0.296***	0.272***	0.509***	0.515***	0.413***	0.476***	0.222***	0.171**	0.274***	0.248***
	(0.0978)	(0.126)	(0.0593)	(0.0641)	(0.0527)	(0.0571)	(0.114)	(0.128)	(0.118)	(0.136)	(0.0673)	(0.0691)	(0.0899)	(0.0906)
Observations	203	203	203	203	203	203	203	203	203	203	203	203	203	203
R-squared	0.405	0.544	0.137	0.200	0.249	0.263	0.246	0.254	0.182	0.195	0.244	0.319	0.316	0.342
Horizon dummy		YES		YES		YES		YES		YES		YES		YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.16: Omitting dropout with supply controls, Type MS

Type S

	2011 01-05		2012 01-05		2013 01-05		2014 01-05		2015 01-05		2016 01-05		2017 01-05		2018 01-03	
VARIABLES																
gdp growth	-0.0201	0.0870**	0.192***	0.137**	0.151***	0.146**	0.171**	0.197**	0.169**	0.120	0.226***	0.197**	0.414***	0.457***	0.543***	0.548***
	(0.0388)	(0.0418)	(0.0672)	(0.0640)	(0.0556)	(0.0600)	(0.0816)	(0.0844)	(0.0736)	(0.0729)	(0.0800)	(0.0801)	(0.0527)	(0.0564)	(0.137)	(0.140)
NY WTI Oil	2.810***	0.975**	0.890***	0.571***	0.605**	0.639**	0.407	0.406	1.903***	1.664***	0.948***	0.885***	1.143***	1.152***	0.838***	0.725**
	(0.469)	(0.440)	(0.228)	(0.212)	(0.256)	(0.280)	(0.457)	(0.477)	(0.235)	(0.261)	(0.203)	(0.263)	(0.338)	(0.336)	(0.312)	(0.351)
USD/Yen rate	0.161	0.0679	1.803**	1.345*	0.571	0.427	2.250***	2.503***	0.659	0.244	2.176***	0.566	1.856***	1.738***	1.121	1.480*
	(0.676)	(0.428)	(0.738)	(0.745)	(0.382)	(0.573)	(0.777)	(0.789)	(1.098)	(1.021)	(0.528)	(0.796)	(0.346)	(0.326)	(0.743)	(0.890)
Constant	-0.202**	-0.0780	-0.539***	-0.417***	-0.200**	-0.175	0.707***	0.672***	0.761***	0.812***	0.332***	0.319***	0.142*	0.0197	0.245***	0.221***
	(0.0949)	(0.0714)	(0.124)	(0.118)	(0.0871)	(0.120)	(0.0690)	(0.0716)	(0.172)	(0.193)	(0.109)	(0.112)	(0.0610)	(0.0823)	(0.0919)	(0.0899)
Observations	145	145	145	145	145	145	145	145	145	145	145	145	145	145	87	87
R-squared	0.395	0.498	0.303	0.385	0.230	0.234	0.120	0.179	0.395	0.489	0.470	0.502	0.385	0.399	0.287	0.290
Horizon dummy		YES		YES		YES		YES		YES		YES		YES		YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.17: Omitting dropout with supply controls, Type S

3.12 Tables (Adding US and China GDP growth rate)

Type LM

VARIABLES	2011 01-05		2012 01-05		2013 01-05		2014 01-05		2015 01-05		2016 01-05		2017 01-05		2018 01-03	
gdp growth	0.0539	0.0626	0.194***	0.197***	0.176***	0.167***	0.501***	0.503***	0.323***	0.337***	0.389***	0.378***	0.473***	0.474***	0.745***	0.745***
	(0.0501)	(0.0736)	(0.0565)	(0.0565)	(0.0521)	(0.0497)	(0.0681)	(0.0691)	(0.110)	(0.107)	(0.0906)	(0.0902)	(0.0866)	(0.0876)	(0.127)	(0.128)
NY WTI Oil	-1.180***	-0.981**	-0.393	-0.369	0.318	0.160	4.627***	4.665***	1.874***	2.002***	0.958**	1.109**	0.920***	0.923***	1.644***	1.676***
	(0.418)	(0.436)	(0.393)	(0.380)	(0.591)	(0.609)	(0.674)	(0.694)	(0.611)	(0.596)	(0.416)	(0.439)	(0.330)	(0.335)	(0.570)	(0.570)
USD/Yen rate	0.409	0.465	-0.508	-0.513	0.0332	-0.244	4.072***	3.875***	1.919	1.922	-0.920	-0.173	-1.192	-1.167	3.933***	3.826***
	(0.585)	(0.600)	(0.572)	(0.597)	(0.873)	(0.873)	(1.158)	(1.145)	(1.801)	(1.781)	(1.075)	(1.098)	(0.773)	(0.780)	(1.158)	(1.155)
gdp growth (USA)	-0.122*	-0.138**	0.202***	0.199***	0.110	0.116*	0.156	0.143	0.248	0.239	0.0780	0.0312	0.133*	0.135*	-0.257***	-0.257***
	(0.0642)	(0.0651)	(0.0429)	(0.0436)	(0.0692)	(0.0699)	(0.108)	(0.111)	(0.164)	(0.170)	(0.111)	(0.108)	(0.0691)	(0.0710)	(0.0750)	(0.0790)
gdp growth (China)	0.0904***	0.0851***	0.0461	0.0547	0.0169	0.0506	-0.106	-0.0988	0.108	0.0819	0.458***	0.414***	0.0788	0.0852	0.590***	0.580***
	(0.0276)	(0.0282)	(0.0582)	(0.0587)	(0.107)	(0.112)	(0.0704)	(0.0724)	(0.138)	(0.159)	(0.104)	(0.103)	(0.136)	(0.137)	(0.197)	(0.202)
Constant	0.286**	0.259	-0.217**	-0.213**	0.349***	0.353***	-0.0270	-0.00941	0.406*	0.357	1.101***	1.027***	0.338**	0.339**	0.681***	0.674***
	(0.131)	(0.187)	(0.105)	(0.105)	(0.0434)	(0.0433)	(0.167)	(0.171)	(0.244)	(0.236)	(0.109)	(0.112)	(0.144)	(0.147)	(0.157)	(0.157)
Observations	157	157	156	156	162	162	159	159	165	165	168	168	183	183	109	109
R-squared	0.138	0.163	0.229	0.249	0.102	0.134	0.413	0.420	0.168	0.173	0.331	0.374	0.372	0.373	0.476	0.477
Horizon dummy	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.18: Adding US and China GDP growth rate, Type LM

Type MS

VARIABLES	2011 06-12		2012 06-12		2013 06-12		2014 06-12		2015 06-12		2016 06-12		2017 06-12	
gdp growth	0.367***	0.276***	0.230***	0.235***	0.436***	0.448***	0.457***	0.472***	0.380***	0.372***	0.177***	0.221***	0.322***	0.322***
	(0.0590)	(0.0602)	(0.0368)	(0.0385)	(0.0700)	(0.0762)	(0.0714)	(0.0767)	(0.0746)	(0.0782)	(0.0621)	(0.0605)	(0.0716)	(0.0697)
NY WTI Oil	0.787**	0.416	0.717***	0.755***	1.456***	1.379***	1.913***	1.899***	0.724**	0.572	1.317***	1.447***	2.276***	2.503***
	(0.385)	(0.330)	(0.201)	(0.211)	(0.476)	(0.505)	(0.358)	(0.491)	(0.316)	(0.356)	(0.257)	(0.245)	(0.327)	(0.330)
USD/Yen rate	0.780	0.607	-1.867***	-1.794***	2.571***	2.553***	2.059**	1.987**	-0.987	-0.891	2.720***	3.631***	1.282**	1.256**
	(0.589)	(0.582)	(0.455)	(0.465)	(0.673)	(0.666)	(0.808)	(0.834)	(1.189)	(1.208)	(0.668)	(0.752)	(0.543)	(0.559)
gdp growth (USA)	0.0867	-0.0466	0.0747	0.0631	0.184***	0.179***	0.136	0.133	0.189	0.165	0.358***	0.317***	0.203**	0.164*
	(0.0595)	(0.0576)	(0.0485)	(0.0491)	(0.0588)	(0.0617)	(0.103)	(0.105)	(0.128)	(0.135)	(0.0932)	(0.0842)	(0.0946)	(0.0914)
gdp growth (China)	-0.0324	-0.0371	0.0698*	0.0487	0.0537	0.0569	0.00761	0.00934	0.311***	0.296***	0.170**	0.164**	0.191	0.326**
	(0.0331)	(0.0303)	(0.0416)	(0.0427)	(0.0638)	(0.0795)	(0.0963)	(0.0969)	(0.111)	(0.111)	(0.0736)	(0.0728)	(0.138)	(0.140)
Constant	-0.975***	-0.633***	-0.173**	-0.177**	0.219***	0.219***	0.399***	0.380***	0.513***	0.529***	0.117	0.0644	0.418***	0.487***
	(0.128)	(0.142)	(0.0680)	(0.0724)	(0.0700)	(0.0728)	(0.118)	(0.126)	(0.135)	(0.142)	(0.0846)	(0.0830)	(0.118)	(0.117)
Observations	238	238	230	230	237	237	240	240	256	256	254	254	278	278
R-squared	0.401	0.499	0.316	0.330	0.255	0.261	0.284	0.293	0.222	0.229	0.337	0.394	0.360	0.403
Horizon dummy	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.19: Adding US and China GDP growth rate, Type MS

Type S

VARIABLES	2011 01-05		2012 01-05		2013 01-05		2014 01-05		2015 01-05		2016 01-05		2017 01-05		2018 01-03	
gdp growth	-0.0202	0.0906**	0.225***	0.178***	0.135***	0.135**	0.139**	0.163**	0.131*	0.140**	0.120	0.135*	0.310***	0.308***	0.413***	0.401***
	(0.0327)	(0.0419)	(0.0683)	(0.0684)	(0.0510)	(0.0543)	(0.0669)	(0.0676)	(0.0689)	(0.0649)	(0.0791)	(0.0803)	(0.0724)	(0.0769)	(0.124)	(0.121)
NY WTI Oil	2.466***	1.385***	0.836***	0.624***	0.574**	0.598**	0.556	0.488	1.642***	1.400***	0.890***	0.737***	0.846***	0.827**	0.698**	0.817***
	(0.384)	(0.464)	(0.217)	(0.237)	(0.236)	(0.248)	(0.391)	(0.402)	(0.191)	(0.236)	(0.184)	(0.232)	(0.316)	(0.321)	(0.294)	(0.280)
USD/Yen rate	0.0327	0.125	1.773**	1.406*	0.889***	0.818*	1.855***	1.940***	0.0224	0.174	2.411***	0.956	0.617	0.614	0.375	-0.00519
	(0.485)	(0.424)	(0.709)	(0.729)	(0.330)	(0.459)	(0.650)	(0.644)	(0.963)	(0.880)	(0.543)	(0.640)	(0.469)	(0.466)	(0.760)	(0.802)
gdp growth (USA)	0.00920	-0.0691	-0.0269	-0.0200	0.162***	0.165***	0.157*	0.181**	0.228***	0.0334	0.0455	-0.0510	0.244***	0.248***	0.112	0.120
	(0.0634)	(0.0601)	(0.0836)	(0.0847)	(0.0531)	(0.0540)	(0.0828)	(0.0826)	(0.0711)	(0.0938)	(0.0965)	(0.0893)	(0.0720)	(0.0803)	(0.130)	(0.134)
gdp growth (China)	0.0575	0.0156	-0.00554	0.0283	0.141**	0.153**	0.128	0.148	0.360***	0.234**	0.387***	0.395***	-0.0489	-0.0533	0.535**	0.564**
	(0.0553)	(0.0511)	(0.0484)	(0.0510)	(0.0614)	(0.0639)	(0.105)	(0.105)	(0.129)	(0.116)	(0.0996)	(0.0955)	(0.106)	(0.108)	(0.224)	(0.228)
Constant	-0.109	-0.117	-0.590***	-0.460***	-0.157*	-0.152	0.649***	0.611***	0.806***	0.758***	0.612***	0.480***	0.114	0.114	0.493**	0.510**
	(0.117)	(0.104)	(0.143)	(0.140)	(0.0831)	(0.109)	(0.107)	(0.109)	(0.150)	(0.169)	(0.140)	(0.141)	(0.126)	(0.129)	(0.235)	(0.235)
Observations	209	209	194	194	197	197	199	199	207	207	213	213	209	209	119	119
R-squared	0.328	0.457	0.325	0.380	0.284	0.288	0.167	0.220	0.391	0.461	0.479	0.508	0.253	0.254	0.346	0.349
Horizon dummy	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.20: Adding US and China GDP growth rate, Type S

3.13 Tables (IV estimation, without supply shock controls)

Type L										
	2013 06-12		2014 06-12		2015 06-12		2016 06-12		2017 06-12	
VARIABLES										
gdp growth	0.555***	0.555***	0.198	0.200	0.215**	0.211**	0.714***	0.715***	0.492***	0.489***
	(0.0623)	(0.0623)	(0.154)	(0.150)	(0.0845)	(0.0848)	(0.0474)	(0.0474)	(0.137)	(0.136)
Constant	0.250***	0.250***	1.043***	1.041***	1.220***	1.221***	0.274***	0.274***	0.652***	0.654***
	(0.0768)	(0.0768)	(0.209)	(0.203)	(0.0268)	(0.0268)	(0.0494)	(0.0498)	(0.101)	(0.0997)
Observations	243	243	244	244	225	225	236	236	220	220
R-squared	0.257	0.261	0.024	0.025	0.053	0.063	0.473	0.475	0.102	0.108
Horizon dummy		YES		YES		YES		YES		YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3.21: IV estimation without supply controls, Type L

Type LM																
	2011 02-05		2012 02-05		2013 02-05		2014 02-05		2015 02-05		2016 02-05		2017 02-05		2018 02-03	
VARIABLES																
gdp growth	0.143*	0.200*	0.257***	0.249***	0.156***	0.150***	0.512***	0.511***	0.364***	0.369***	0.481***	0.456***	0.639***	0.639***	0.807***	0.809***
	(0.0858)	(0.118)	(0.0890)	(0.0891)	(0.0460)	(0.0464)	(0.0821)	(0.0812)	(0.136)	(0.136)	(0.130)	(0.126)	(0.0851)	(0.0848)	(0.161)	(0.161)
Constant	-0.0532	-0.189	-0.236*	-0.227*	0.461***	0.463***	0.345***	0.344***	0.609**	0.602**	0.921***	0.927***	0.303***	0.304***	0.284**	0.283**
	(0.204)	(0.280)	(0.129)	(0.129)	(0.0219)	(0.0221)	(0.112)	(0.111)	(0.243)	(0.242)	(0.0327)	(0.0321)	(0.0963)	(0.0959)	(0.120)	(0.119)
Observations	124	124	122	122	128	128	128	128	132	132	133	133	146	146	74	74
R-squared	0.019	0.024	0.134	0.157	0.096	0.106	0.237	0.242	0.084	0.085	0.146	0.193	0.324	0.325	0.233	0.234
Horizon dumm		YES		YES		YES		YES		YES		YES		YES		YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.22: IV estimation without supply controls, Type LM

Type MS														
	2011 07-12		2012 07-12		2013 07-12		2014 07-12		2015 07-12		2016 07-12		2017 07-12	
VARIABLES														
gdp growth	0.369***	0.279***	0.263***	0.267***	0.416***	0.434***	0.585***	0.650***	0.535***	0.483***	0.503***	0.518***	0.546***	0.558***
	(0.0452)	(0.0605)	(0.0562)	(0.0584)	(0.0893)	(0.0948)	(0.0987)	(0.0948)	(0.0852)	(0.0883)	(0.0873)	(0.0826)	(0.0918)	(0.0912)
Constant	-0.911***	-0.690***	-0.261***	-0.267***	0.494***	0.481***	0.310**	0.223*	0.178	0.262*	0.185**	0.173**	0.222**	0.207**
	(0.107)	(0.146)	(0.0885)	(0.0919)	(0.0502)	(0.0539)	(0.139)	(0.135)	(0.146)	(0.152)	(0.0838)	(0.0791)	(0.101)	(0.100)
Observations	202	202	200	200	201	201	204	204	219	219	219	219	242	242
R-squared	0.389	0.487	0.137	0.156	0.177	0.190	0.120	0.185	0.159	0.188	0.175	0.217	0.175	0.191
Horizon dumm		YES		YES		YES		YES		YES		YES		YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.23: IV estimation without supply controls, Type MS

Type S																
	2011 02-05		2012 02-05		2013 02-05		2014 02-05		2015 02-05		2016 02-05		2017 02-05		2018 02-03	
VARIABLES																
gdp growth	-0.155***	0.182*	0.365***	0.249***	0.255***	0.210**	0.216***	0.232***	0.394***	0.342***	0.447***	0.302***	0.372***	0.416***	0.505***	0.504***
	(0.0446)	(0.0977)	(0.0836)	(0.0809)	(0.0689)	(0.0892)	(0.0795)	(0.0790)	(0.0952)	(0.0887)	(0.0902)	(0.0970)	(0.0872)	(0.0944)	(0.159)	(0.160)
Constant	0.353***	0.0250	-0.806***	-0.576***	-0.305**	-0.206	0.797***	0.784***	-0.274*	-0.180	-0.158*	-0.00505	0.351***	0.294**	0.291	0.293
	(0.0503)	(0.102)	(0.165)	(0.157)	(0.153)	(0.200)	(0.0560)	(0.0555)	(0.160)	(0.150)	(0.0951)	(0.102)	(0.112)	(0.122)	(0.198)	(0.198)
Observations	166	166	154	154	156	156	161	161	165	165	166	166	166	166	80	80
R-squared	0.045	0.269	0.086	0.285	0.098	0.112	0.055	0.078	0.064	0.148	0.182	0.248	0.077	0.084	0.270	0.270
Horizon dumm		YES		YES		YES		YES		YES		YES		YES		YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3.24: IV estimation without supply controls, Type S

3.14 Tables (IV estimation, with supply shock controls)

Type LM																
	2011 02-05		2012 02-05		2013 02-05		2014 02-05		2015 02-05		2016 02-05		2017 02-05		2018 02-03	
VARIABLES																
gdp growth	0.107	0.174	0.222***	0.218**	0.162***	0.157***	0.498***	0.498***	0.407***	0.408***	0.380***	0.362***	0.526***	0.525***	0.819***	0.821***
	(0.0974)	(0.132)	(0.0859)	(0.0855)	(0.0462)	(0.0464)	(0.0702)	(0.0695)	(0.108)	(0.108)	(0.130)	(0.127)	(0.100)	(0.0999)	(0.158)	(0.157)
NY WTI Oil	-0.726	-0.716	0.466	0.520	-0.0230	-0.0401	4.158***	4.236***	2.069***	2.067***	1.541***	1.433***	1.104***	1.109***	1.589***	1.592***
	(0.490)	(0.511)	(0.509)	(0.490)	(0.524)	(0.525)	(0.620)	(0.612)	(0.638)	(0.639)	(0.498)	(0.491)	(0.423)	(0.427)	(0.564)	(0.571)
USD/Yen rate	0.110	0.226	0.0314	0.0568	1.494*	1.402*	2.805**	2.767**	2.664	2.648	0.108	0.579	-1.259*	-1.255*	0.588	0.568
	(0.737)	(0.745)	(0.711)	(0.722)	(0.844)	(0.846)	(1.288)	(1.258)	(1.797)	(1.780)	(1.168)	(1.172)	(0.655)	(0.657)	(1.782)	(1.756)
Constant	0.0426	-0.121	-0.186	-0.185	0.428***	0.432***	0.250***	0.248***	0.402***	0.401***	0.672***	0.687***	0.366***	0.367***	0.293**	0.292**
	(0.247)	(0.327)	(0.132)	(0.131)	(0.0343)	(0.0346)	(0.0932)	(0.0929)	(0.168)	(0.167)	(0.0884)	(0.0846)	(0.0959)	(0.0955)	(0.118)	(0.117)
Observations	121	121	120	120	128	128	126	126	131	131	127	127	145	145	73	73
R-squared	0.033	0.039	0.146	0.166	0.117	0.124	0.394	0.403	0.195	0.195	0.223	0.259	0.370	0.371	0.342	0.342
Horizon dumm		YES		YES		YES		YES		YES		YES		YES		YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.25: IV estimation with supply controls, Type LM

Type MS														
	2011 07-12		2012 07-12		2013 07-12		2014 07-12		2015 07-12		2016 07-12		2017 07-12	
VARIABLES														
gdp growth	0.386***	0.310***	0.230***	0.236***	0.462***	0.481***	0.610***	0.638***	0.482***	0.458***	0.388***	0.411***	0.438***	0.450***
	(0.0442)	(0.0591)	(0.0467)	(0.0478)	(0.0936)	(0.101)	(0.0954)	(0.0956)	(0.0813)	(0.0834)	(0.0832)	(0.0761)	(0.0986)	(0.0961)
NY WTI Oil	0.779*	0.522	0.916***	0.923***	1.721***	1.567***	1.848***	1.536***	0.731**	0.493	1.032***	1.171***	2.033***	2.220***
	(0.436)	(0.391)	(0.221)	(0.223)	(0.552)	(0.586)	(0.373)	(0.528)	(0.346)	(0.363)	(0.292)	(0.287)	(0.334)	(0.333)
USD/Yen rate	0.649	0.197	1.492***	1.479***	2.183***	2.186***	1.623	1.933*	-1.581	-1.380	2.443***	3.166***	1.705***	1.809***
	(0.607)	(0.544)	(0.479)	(0.472)	(0.746)	(0.778)	(0.988)	(1.027)	(1.115)	(1.113)	(0.661)	(0.801)	(0.565)	(0.568)
Constant	-0.964***	-0.766***	-0.186**	-0.196**	0.352***	0.342***	0.269**	0.206	0.233*	0.286**	0.101	0.0459	0.228**	0.204**
	(0.0996)	(0.142)	(0.0767)	(0.0787)	(0.0617)	(0.0653)	(0.137)	(0.147)	(0.128)	(0.138)	(0.0842)	(0.0841)	(0.102)	(0.100)
Observations	196	196	197	197	198	198	199	199	218	218	219	219	242	242
R-squared	0.418	0.490	0.227	0.246	0.233	0.245	0.234	0.243	0.185	0.199	0.258	0.309	0.335	0.364
Horizon dumm		YES		YES		YES		YES		YES		YES		YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.26: IV estimation with supply controls, Type MS

Type S																
	2011 02-05		2012 02-05		2013 02-05		2014 02-05		2015 02-05		2016 02-05		2017 02-05		2018 02-03	
VARIABLES																
gdp growth	0.0200	0.170*	0.279***	0.223**	0.215**	0.196**	0.169**	0.193**	0.305***	0.219***	0.234**	0.164*	0.359***	0.392***	0.547***	0.547***
	(0.0637)	(0.0928)	(0.106)	(0.0991)	(0.0840)	(0.0929)	(0.0853)	(0.0850)	(0.0846)	(0.0821)	(0.0958)	(0.0969)	(0.0827)	(0.0875)	(0.163)	(0.164)
NY WTI Oil	2.362***	1.363***	1.059***	0.801***	0.754***	0.760***	0.428	0.324	1.106***	1.316***	0.762***	0.968***	1.248***	1.252***	0.696*	0.653*
	(0.475)	(0.510)	(0.254)	(0.260)	(0.274)	(0.284)	(0.441)	(0.440)	(0.284)	(0.266)	(0.220)	(0.262)	(0.366)	(0.363)	(0.377)	(0.367)
USD/Yen rate	0.221	-0.0267	1.387	1.014	0.480	0.405	2.112***	2.107***	0.686	0.609	2.148***	1.268*	0.837*	0.713	0.737	0.906
	(0.593)	(0.508)	(0.844)	(0.829)	(0.470)	(0.611)	(0.761)	(0.735)	(1.214)	(1.052)	(0.601)	(0.719)	(0.482)	(0.469)	(0.872)	(0.849)
Constant	-0.167	-0.164	-0.710***	-0.581***	-0.313**	-0.264	0.730***	0.712***	0.224	0.462*	0.282**	0.359**	0.183	0.148	0.152	0.156
	(0.122)	(0.115)	(0.199)	(0.186)	(0.160)	(0.203)	(0.0671)	(0.0660)	(0.235)	(0.245)	(0.137)	(0.140)	(0.131)	(0.136)	(0.203)	(0.203)
Observations	164	164	151	151	156	156	160	160	163	163	162	162	166	166	80	80
R-squared	0.237	0.325	0.263	0.345	0.145	0.150	0.106	0.129	0.203	0.318	0.313	0.351	0.181	0.182	0.326	0.329
Horizon dumm		YES		YES		YES		YES		YES		YES		YES		YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.27: IV estimation with supply controls, Type S

3.15 Tables (Unemployment gap, without supply shock controls)

Type LM																
	2011 01-05		2012 01-05		2013 01-05		2014 01-05		2015 01-05		2016 01-05		2017 01-05		2018 01-03	
VARIABLES																
gdp growth	-0.0766	-0.117	-0.220**	-0.217**	-0.559***	-0.480**	-0.595***	-0.594***	-0.683***	-0.747***	-0.510**	-0.524***	-0.723**	-0.738***	-0.925***	-0.948***
	(0.0850)	(0.0882)	(0.0966)	(0.0973)	(0.185)	(0.196)	(0.117)	(0.121)	(0.205)	(0.208)	(0.208)	(0.194)	(0.228)	(0.241)	(0.253)	(0.259)
Constant	0.277***	0.287***	0.0881***	0.0878***	0.292***	0.317***	0.612***	0.613***	0.673***	0.619***	0.646***	0.645***	0.535***	0.590***	0.153	0.135
	(0.0330)	(0.0336)	(0.0244)	(0.0245)	(0.0681)	(0.0710)	(0.0797)	(0.0816)	(0.173)	(0.175)	(0.128)	(0.119)	(0.178)	(0.188)	(0.206)	(0.210)
Observations	218	218	209	209	207	207	213	213	213	213	213	213	206	206	118	118
R-squared	0.005	0.072	0.032	0.053	0.082	0.111	0.119	0.119	0.070	0.083	0.026	0.097	0.002	0.003	0.113	0.117
Horizon dumm		YES		YES		YES		YES		YES		YES		YES		YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.28: Using unemployment gap without supply controls, Type LM

Type MS

	2011 06-12		2012 06-12		2013 06-12		2014 06-12		2015 06-12		2016 06-12		2017 06-12	
VARIABLES														
gdp growth	-0.120**	-0.122*	-0.438***	-0.424***	-0.385***	-0.384***	-0.170	-0.246	-0.0546	-0.292*	-0.0546	-0.292*	0.132	0.101
	(0.0586)	(0.0674)	(0.0858)	(0.0858)	(0.121)	(0.123)	(0.166)	(0.158)	(0.148)	(0.169)	(0.148)	(0.169)	(0.174)	(0.175)
Constant	0.0231	0.0491***	0.0661***	0.0686***	0.581***	0.581***	0.973***	0.928***	0.659***	0.525***	0.659***	0.525***	0.978***	0.949***
	(0.0219)	(0.0178)	(0.0190)	(0.0189)	(0.0658)	(0.0656)	(0.0960)	(0.0924)	(0.0882)	(0.0975)	(0.0882)	(0.0975)	(0.160)	(0.160)
Observations	312	312	306	306	311	311	311	311	317	317	317	317	291	291
R-squared	0.009	0.476	0.109	0.147	0.029	0.032	0.004	0.100	0.000	0.058	0.000	0.058	0.002	0.014
Horizon dumm		YES		YES		YES		YES		YES		YES		YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3.29: Using unemployment gap without supply controls, Type MS

Type S

	2011 01-05		2012 01-05		2013 01-05		2014 01-05		2015 01-05		2016 01-05		2017 01-05		2018 01-03	
VARIABLES																
gdp growth	0.125	-0.209*	-0.389***	-0.438***	-0.353***	-0.222*	-0.359**	-0.311*	0.609**	0.0202	-0.178	0.000810	-0.0125	-0.0136	-0.280	-0.269
	(0.129)	(0.108)	(0.118)	(0.101)	(0.123)	(0.127)	(0.148)	(0.163)	(0.235)	(0.216)	(0.354)	(0.264)	(0.166)	(0.176)	(0.245)	(0.273)
Constant	0.0256	0.269***	-0.106***	-0.106***	0.137***	0.169***	0.746***	0.772***	0.950***	0.521***	0.276	0.394**	0.803***	0.803***	0.655***	0.666**
	(0.0929)	(0.0777)	(0.0167)	(0.0142)	(0.0305)	(0.0305)	(0.0799)	(0.0871)	(0.169)	(0.157)	(0.222)	(0.166)	(0.114)	(0.120)	(0.235)	(0.261)
Observations	231	231	218	218	216	216	224	224	224	224	225	225	216	216	122	122
R-squared	0.005	0.407	0.054	0.324	0.042	0.122	0.048	0.057	0.033	0.287	0.001	0.381	0.000	0.015	0.012	0.022
Horizon dumn		YES		YES		YES		YES		YES		YES		YES		YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3.30: Using unemployment gap without supply controls, Type S

3.16 Tables (Unemployment gap, with supply shock controls)

Type LM																
	2011 01-05		2012 01-05		2013 01-05		2014 01-05		2015 01-05		2016 01-05		2017 01-05		2018 01-03	
VARIABLES																
gdp growth	-0.275***	-0.306***	-0.384***	-0.380***	-0.717***	-0.670***	-0.745***	-0.734***	-0.836***	-0.919***	-0.758***	-0.799***	-0.769***	-0.775***	-0.728***	-0.747***
	(0.0963)	(0.103)	(0.0955)	(0.0965)	(0.197)	(0.211)	(0.117)	(0.121)	(0.239)	(0.243)	(0.212)	(0.187)	-0.215	(0.228)	(0.245)	(0.247)
NY WTI Oil	-1.121**	-0.795	0.435	0.488	0.330	0.303	3.169***	3.217***	1.088*	1.177**	1.507***	1.718***	1.985***	1.994***	1.491**	1.527**
	(0.525)	(0.512)	(0.495)	(0.493)	(0.509)	(0.516)	(0.760)	(0.778)	(0.583)	(0.574)	(0.396)	(0.411)	(0.346)	(0.354)	(0.609)	(0.607)
USD/Yen rate	-0.764	-0.739	-0.830	-0.782	-0.224	-0.324	2.198**	2.162**	3.661**	3.548**	-1.143	0.161	-2.223***	-2.226***	2.429*	2.383*
	(0.597)	(0.575)	(0.735)	(0.755)	(0.808)	(0.805)	(0.982)	(0.997)	(1.791)	(1.726)	(0.973)	(0.982)	(0.765)	(0.779)	(1.331)	(1.347)
Constant	0.420***	0.419***	0.0957**	0.0932**	0.239***	0.255***	0.441***	0.449***	0.276***	0.202***	0.268*	0.206	0.359***	0.354***	0.318	0.303
	(0.0471)	(0.0482)	(0.0369)	(0.0375)	(0.0696)	(0.0760)	(0.0678)	(0.0692)	(0.0810)	(0.0870)	(0.144)	(0.133)	(0.167)	(0.176)	(0.199)	(0.200)
Observations	161	161	158	158	163	163	162	162	165	165	168	168	188	188	114	114
R-squared	0.091	0.128	0.125	0.142	0.160	0.175	0.331	0.332	0.186	0.202	0.150	0.238	0.176	0.178	0.194	0.201
Horizon dumm		YES		YES		YES		YES		YES		YES		YES		YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.31: Using unemployment gap with supply controls, Type LM

Type MS

VARIABLES	2011 06-12		2012 06-12		2013 06-12		2014 06-12		2015 06-12		2016 06-12		2017 06-12	
gdp growth	0.0132	-0.215*	-0.491***	-0.476***	-0.636***	-0.644***	-0.642***	-0.621***	-0.467**	-0.504***	-0.0897	-0.467***	-0.139	-0.188
	(0.0667)	(0.121)	(0.0811)	(0.0789)	(0.127)	(0.129)	(0.124)	(0.125)	(0.197)	(0.193)	(0.134)	(0.156)	(0.139)	(0.137)
NY WTI Oil	0.915**	0.107	0.558***	0.567**	1.722***	1.680***	1.523***	2.255***	1.266***	0.750**	1.575***	1.696***	2.886***	3.079***
	(0.426)	(0.318)	(0.207)	(0.218)	(0.472)	(0.514)	(0.310)	(0.486)	(0.330)	(0.378)	(0.266)	(0.261)	(0.311)	(0.316)
USD/Yen rate	2.551***	0.622	-1.545***	-1.510***	1.948***	1.917***	2.016**	1.249*	-2.427**	-1.874*	3.209***	3.538***	0.594	0.658
	(0.721)	(0.558)	(0.459)	(0.465)	(0.621)	(0.583)	(0.784)	(0.753)	(1.173)	(1.126)	(0.711)	(0.800)	(0.570)	(0.566)
Constant	-0.0350	0.0522	0.101***	0.102***	0.366***	0.364***	0.670***	0.736***	0.737***	0.750***	0.348***	0.112	0.582***	0.528***
	(0.0343)	(0.0334)	(0.0238)	(0.0233)	(0.0856)	(0.0833)	(0.0865)	(0.0844)	(0.125)	(0.123)	(0.0932)	(0.108)	(0.133)	(0.130)
Observations	239	239	232	232	238	238	240	240	257	257	261	261	285	285
R-squared	0.089	0.450	0.249	0.296	0.099	0.102	0.178	0.206	0.091	0.132	0.163	0.230	0.245	0.269
Horizon dumn		YES		YES		YES		YES		YES		YES		YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.32: Using unemployment gap with supply controls, Type MS

Type S

VARIABLES	2011 01-05		2012 01-05		2013 01-05		2014 01-05		2015 01-05		2016 01-05		2017 01-05		2018 01-03	
gdp growth	-0.0302	-0.148	-0.438***	-0.450***	-0.264**	-0.249**	-0.451***	-0.394**	-0.348***	-0.331***	-0.216	-0.147	0.0712	0.0987	-0.173	-0.192
	(0.108)	(0.104)	(0.109)	(0.100)	(0.113)	(0.119)	(0.149)	(0.163)	(0.201)	(0.194)	(0.249)	(0.230)	(0.152)	(0.163)	(0.259)	(0.276)
NY WTI Oil	2.634***	1.372***	0.821***	0.504*	0.728***	0.736**	1.078**	1.149***	1.779***	1.582***	1.020***	0.855***	1.083***	1.030***	0.718*	0.625
	(0.320)	(0.478)	(0.246)	(0.256)	(0.273)	(0.284)	(0.419)	(0.416)	(0.216)	(0.244)	(0.181)	(0.235)	(0.365)	(0.373)	(0.380)	(0.422)
USD/Yen rate	0.0764	0.339	2.569***	1.871***	1.393***	1.244**	2.763***	2.818***	0.953	0.678	3.191***	1.256*	1.054**	1.124***	0.0674	0.266
	(0.459)	(0.418)	(0.566)	(0.601)	(0.245)	(0.480)	(0.737)	(0.716)	(0.877)	(0.851)	(0.479)	(0.743)	(0.407)	(0.413)	(0.789)	(0.896)
Constant	-0.199***	0.0479	-0.167***	-0.146***	-0.0208	-0.00110	0.554***	0.582***	0.852***	0.886***	0.478***	0.453***	0.682***	0.704***	0.683***	0.672**
	(0.0763)	(0.109)	(0.0191)	(0.0202)	(0.0369)	(0.0619)	(0.0943)	(0.0985)	(0.165)	(0.176)	(0.158)	(0.153)	(0.121)	(0.126)	(0.245)	(0.260)
Observations	211	211	196	196	198	198	202	202	207	207	214	214	214	214	122	122
R-squared	0.325	0.444	0.308	0.397	0.212	0.216	0.148	0.166	0.327	0.435	0.418	0.456	0.086	0.096	0.047	0.049
Horizon dumm		YES		YES		YES		YES		YES		YES		YES		YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.33: Using unemployment gap with supply controls, Type S

3.17 Tables (Hybrid Phillips curve, without supply controls)

Type L							
	2013 06-12		2014 06-12		2015 06-12		2016
VARIABLES							
lagged inflation	0.812***	0.842***	0.940***	0.976***	0.761***	0.821***	0.654***
	(0.0688)	(0.0685)	(0.0682)	(0.0713)	(0.0526)	(0.0575)	(0.0582)
gdp growth	0.209***	0.198***	-0.140*	-0.207**	0.105*	0.107*	0.362***
	(0.0497)	(0.0501)	(0.0842)	(0.0907)	(0.0617)	(0.0617)	(0.0388)
Constant	0.101**	0.0947**	0.412***	0.453***	0.407***	0.339***	0.168***
	(0.0451)	(0.0460)	(0.0891)	(0.0922)	(0.0599)	(0.0660)	(0.0351)
Observations	289	289	289	289	268	268	285
R-squared	0.470	0.484	0.524	0.548	0.472	0.494	0.698
Horizon dummy		YES		YES		YES	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.34: Hybrid Phillips curve without supply controls, Type L

Type LM

	2011 01-05		2012 01-05		2013 01-05		2014 01-05		2015 01-05		2016 01-05		2017 01-05		2018 01-03	
VARIABLES																
lagged inflation	0.396***	0.473***	0.602***	0.741***	0.738***	0.706***	0.962***	0.973***	0.605***	0.790***	0.517***	0.630***	0.916***	0.927***	0.959***	0.967***
	(0.0671)	(0.0805)	(0.0595)	(0.0628)	(0.118)	(0.125)	(0.0745)	(0.0794)	(0.0752)	(0.102)	(0.0544)	(0.0864)	(0.0710)	(0.0710)	(0.0769)	(0.0774)
gdp growth	0.0363	0.125**	0.111**	0.102**	0.129***	0.125***	0.0367	0.0310	0.263***	0.201**	0.356***	0.337***	0.339***	0.342***	0.453***	0.454***
	(0.0509)	(0.0623)	(0.0433)	(0.0401)	(0.0455)	(0.0454)	(0.0518)	(0.0534)	(0.0928)	(0.0940)	(0.0699)	(0.0687)	(0.0441)	(0.0442)	(0.0834)	(0.0837)
Constant	0.122	-0.0920	0.0291	0.0606	0.267***	0.275***	0.386***	0.379***	0.506***	0.518***	0.762***	0.717***	-0.108*	-0.120**	-0.326***	-0.334***
	(0.110)	(0.138)	(0.0704)	(0.0651)	(0.0342)	(0.0363)	(0.104)	(0.115)	(0.156)	(0.153)	(0.0299)	(0.0403)	(0.0620)	(0.0609)	(0.0639)	(0.0632)
Observations	219	219	210	210	209	209	215	215	215	215	215	215	207	207	119	119
R-squared	0.255	0.293	0.473	0.536	0.285	0.296	0.535	0.536	0.322	0.375	0.442	0.465	0.622	0.628	0.658	0.660
Horizon dummy		YES		YES		YES		YES		YES		YES		YES		YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3.35: Hybrid Phillips curve without supply controls, Type LM

3.18 Tables (Hybrid Phillips curve, with supply controls)

Type LM																
	2011 01-05		2012 01-05		2013 01-05		2014 01-05		2015 01-05		2016 01-05		2017 01-05		2018 01-03	
VARIABLES																
lagged inflation	0.317***	0.383***	0.680***	0.789***	0.610***	0.593***	0.900***	0.894***	0.629***	0.797***	0.607***	0.737***	0.877***	0.891***	0.904***	0.914***
	(0.0847)	(0.102)	(0.0659)	(0.0663)	(0.138)	(0.151)	(0.0864)	(0.0930)	(0.0878)	(0.110)	(0.0629)	(0.0914)	(0.0806)	(0.0805)	(0.0627)	(0.0643)
gdp growth	0.0156	0.0887	0.0973**	0.0971**	0.157***	0.155***	0.0857	0.0893	0.262***	0.209**	0.260***	0.251***	0.357***	0.361***	0.479***	0.478***
	(0.0559)	(0.0711)	(0.0440)	(0.0408)	(0.0418)	(0.0424)	(0.0558)	(0.0585)	(0.0960)	(0.0939)	(0.0697)	(0.0671)	(0.0553)	(0.0558)	(0.0718)	(0.0721)
NY WTI Oil	-0.242	-0.264	0.504	0.303	0.592	0.577	2.198***	2.224***	1.955***	1.710***	1.174***	0.966***	0.186	0.156	0.665**	0.611*
	(0.423)	(0.423)	(0.314)	(0.283)	(0.493)	(0.508)	(0.583)	(0.576)	(0.484)	(0.474)	(0.326)	(0.333)	(0.290)	(0.295)	(0.322)	(0.341)
USD/Yen rate	-0.554	-0.510	1.446**	1.433**	0.0671	0.0437	1.204	1.200	2.013	2.401	1.339	1.084	-0.174	-0.0928	2.425***	2.608***
	(0.650)	(0.675)	(0.656)	(0.688)	(0.795)	(0.820)	(0.927)	(0.936)	(1.479)	(1.512)	(0.880)	(0.874)	(0.464)	(0.461)	(0.780)	(0.797)
Constant	0.215*	0.0361	0.0163	0.0347	0.261***	0.266***	0.113**	0.109*	0.316***	0.314***	0.506***	0.483***	-0.112	-0.125*	-0.290***	-0.297***
	(0.129)	(0.170)	(0.0737)	(0.0677)	(0.0473)	(0.0530)	(0.0536)	(0.0562)	(0.0592)	(0.0598)	(0.0602)	(0.0626)	(0.0757)	(0.0746)	(0.0589)	(0.0598)
Observations	160	160	158	158	163	163	162	162	167	167	169	169	188	188	114	114
R-squared	0.156	0.183	0.504	0.552	0.235	0.244	0.567	0.568	0.383	0.427	0.506	0.529	0.610	0.614	0.720	0.723
Horizon dummy		YES		YES		YES		YES		YES		YES		YES		YES

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3.36: Hybrid Phillips curve with supply controls, Type LM

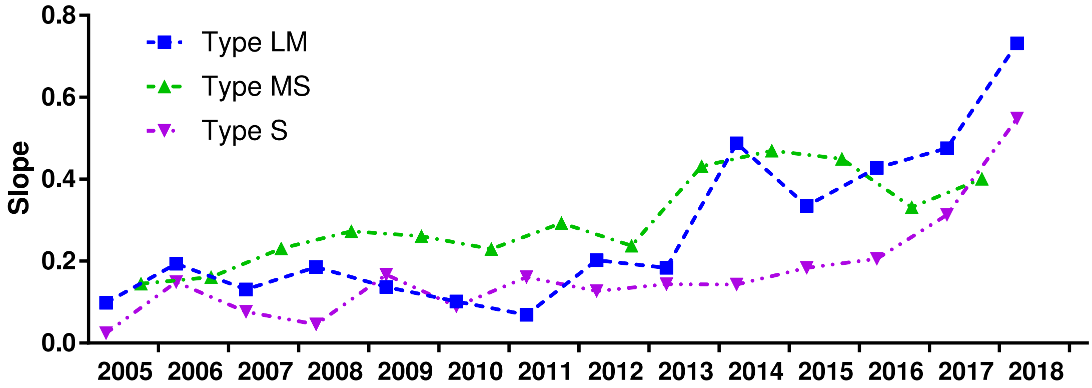

Fig. 3.1: Estimated slope of Phillips curve, benchmark with supply control

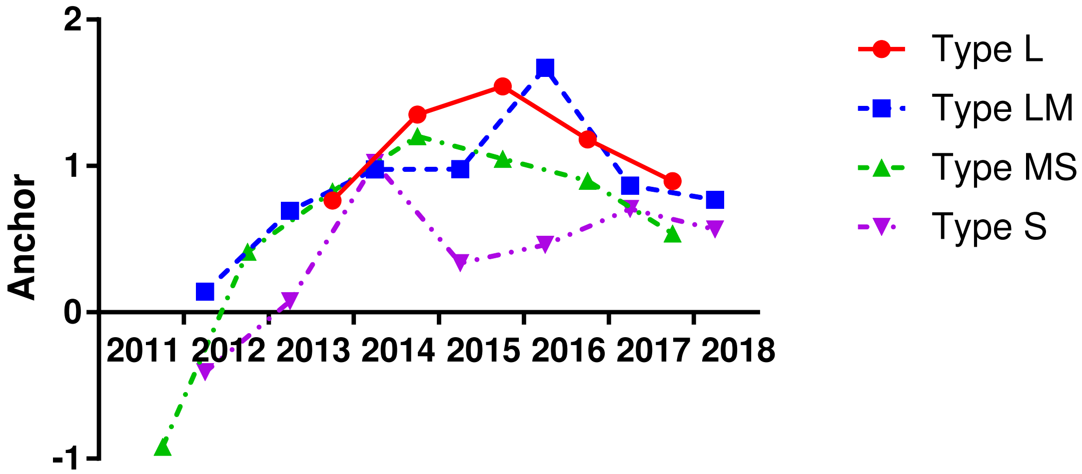

Fig. 3.2: Anchor of inflation expectations, benchmark without supply control

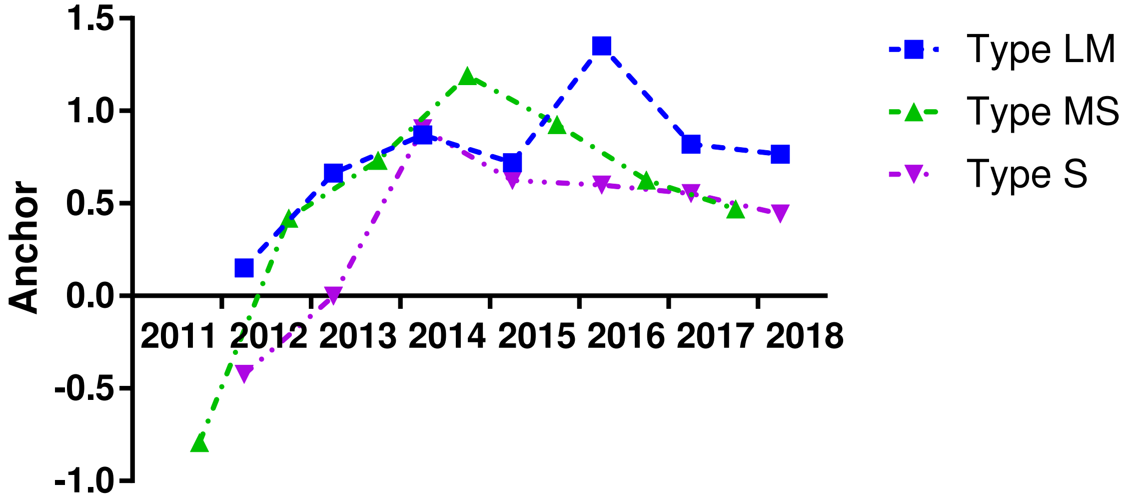

Fig. 3.3: Anchor of inflation expectations, benchmark with supply control

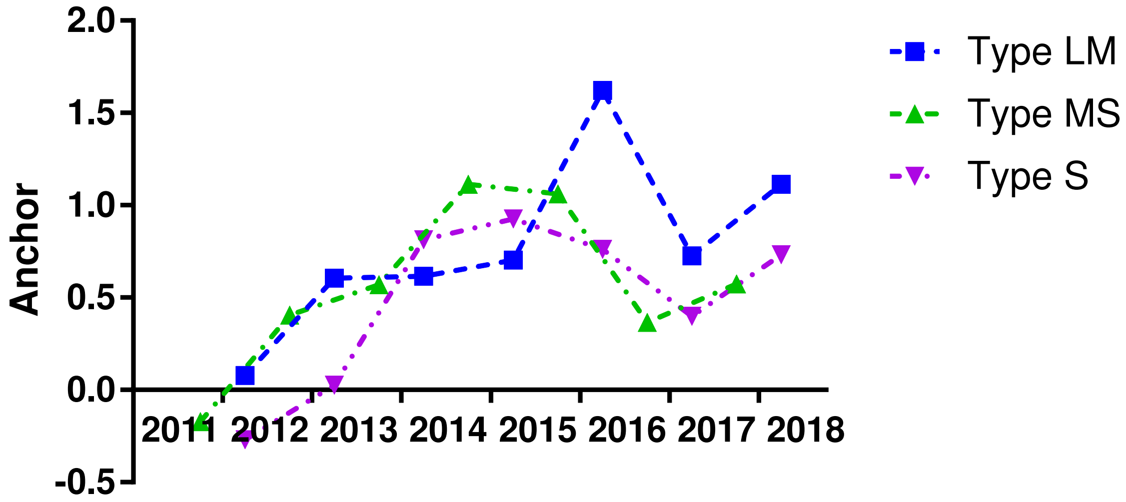

Fig. 3.4: Anchor of inflation expectations, adding US and China GDP growth rate

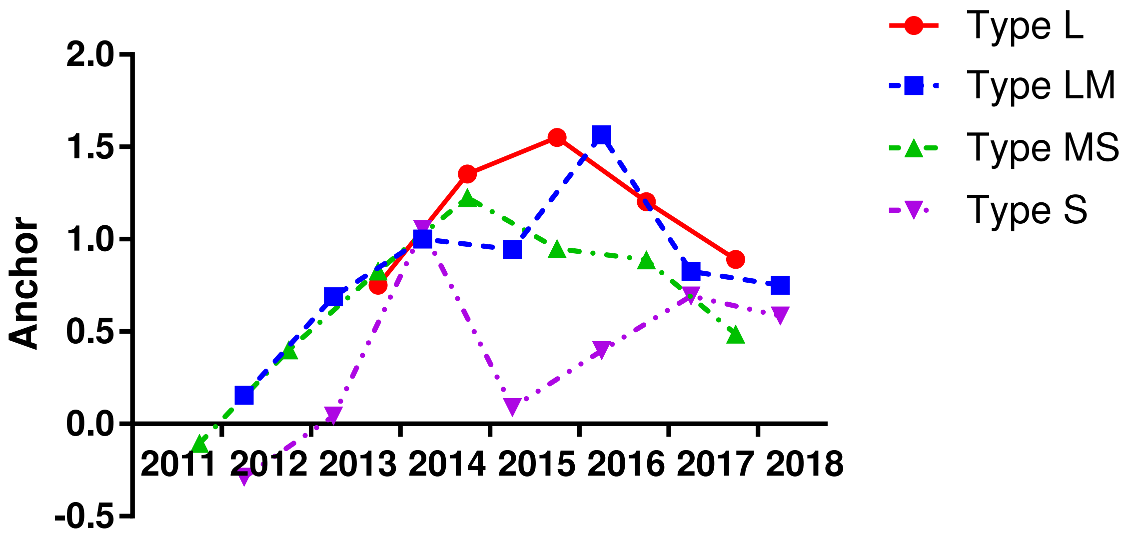

Fig. 3.5: Anchor of inflation expectations, IV estimation without supply control

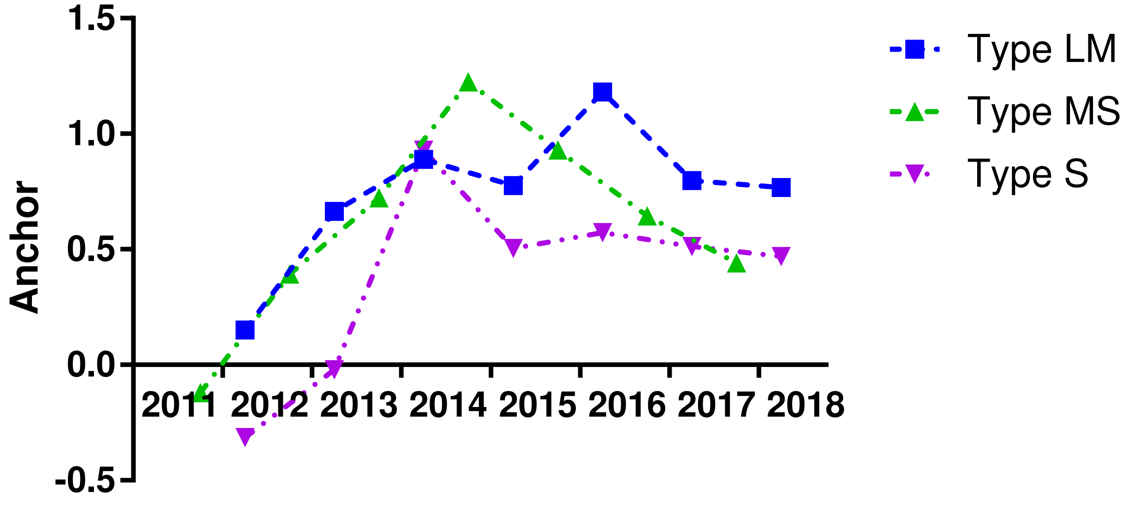

Fig. 3.6: Anchor of inflation expectations, IV estimation with supply control

Chapter 4

Optimal Discretion Policy with a Zero Lower Bound under Parameter Uncertainty

4.1 Introduction

How to conduct monetary policy in the face of uncertainty has always been an interest to both practitioners and academic researchers. In the day-to-day implementation of monetary policy, policymakers must realize that every model is a simplification, necessarily incomplete, and stuck in the world of uncertainty. In general, they have to set their instrument without knowing the “true model" of underlying economy or how their policy will work on the variables which they care about. This difficulty raises the questions about how best to control uncertainty and in particular, what constitutes the optimal monetary policy in the face of uncertainty.

One of the seminal works in this area, Brainard [9], shows that uncertainty about the impact of monetary policy should require a less aggressive policy. In other words, his results suggest that policymakers should change their instrument by less than would be optimal if all parameters were correctly known. After Blinder [8] expresses favorable opinions about the result from the policymaker's perspective, it has been called “Brainard principle” and many researchers have been investigated its validity. In his approach, uncertainty is modeled as the central bank who faces parameter uncertainty of the macroeconomic model. The central bank is assumed to have a prior distribution on the uncertain parameter and conduct the policy based on this distribution. A considerable amount of research has followed the approach, which is referred to a Bayesian approach, and basically support Brainard's result.[1] On the other hand, by using another type of modelling uncertainty, which is referred to a robust-control approach, some literature suggest the opposite result, which recommends a more aggressive policy to deal with parameter uncertainty.[2] Even with the Bayesian approach, there exists some literature which does not support the Brainard principle.[3] So far the results are mixed and there is no consensus about it.

This chapter contributes to discussion above by additional aspects. In particular, we analyze the optimal monetary policy in an economy with an occasionally binding zero lower bound (ZLB) constraint on nominal interest rates, controlled by the central bank who faces parameter uncertainty. When the nominal rate has reached ZLB, the central bank cannot stimulate the economy in the usual manner, which is said to be in a liquidity trap. Motivated by the real experience of Japan from the end of 1990s and the countries all over the world after the global financial crisis in 2008, researchers start to investigate the phenomena and many useful ideas are suggested.

Among them, this chapter focuses on the argument of optimal discretionary policy with the ZLB constraint first examined by Adam and Billi [1]. In contrast to the commitment policy by which the central bank can credibly achieve higher expected

[1]For example, see Clarida and Gertler [11], Estrella and Mishkin [22], Martin and Salmon [54], Svensson [84], Sack [75], Söderström [81], Söderström [82], Rudebusch [74] and Rudebusch [73].

[2]See Stock [83], Tetlow and Von Zur Muehlen [87], Onatski [70], Onatski and Stock [69], Onatski and Williams [71], Giannoni [30], Giannoni [31], and Traficante [88].

[3]See Kimura and Kurozumi [41] and Kurozumi [48].

inflation and a lower real interest rate even with the ZLB constraints, the discretionary policy is deeply involved with uncertainty. As argued in Adam and Billi [1]and Nakov [63], with an occasionally (i.e., stochastically) ZLB constraint, the possibility of future ZLB episodes lowers inflation expectations of private agents, creates a trade-off for discretionary central banks between inflation and output stabilization, even without explicit real shocks that generate the trade-off. This "deflationary bias" phenomena shows a great example that uncertainty about future causes unexpected result, especially when the central bank does not have a credible commitment device.

In this chapter, we theoretically derive the optimal discretionary policy with the stochastic ZLB constraint with parameter uncertainty. We consider the central bank who faces parameter uncertainty about the intertemporal elasticity of substitution and inflation persistence. Both parameters are significant for the central bank's decision in the face of a liquidity trap as it crucially affects the size of output contraction and the effectiveness of the monetary policy in such a situation. In addition, the estimated values of these parameters vary widely among the literature and so it is reasonable to assume that the central bank also faces the same type of uncertainty in reality. By using the Bayesian approach, we derive the optimal discretionary policy to deal with parameter uncertainty and the ZLB constraint at the same time, argue its implication, and contribute to the previous literature of monetary policy with parameter uncertainty, which generally abstracts from the ZLB issue.

The chapter proceeds as follows: Section 2 presents our baseline model. Section 3 reviews the optimal discretionary without parameter uncertainty. Section 4 illustrates the effect of parameter uncertainty on the discretionary central bank. Finally, Section 5 concludes.

4.2 Baseline model

Our analysis is based on a New Keynesian model, the well-known monetary policy model developed by Woodford [94]. The economy consists of a representative household, a continuum of monopolistically competitive firms facing restrictions on the frequency of price adjustments à la Calvo [10], and a central bank. The household's consuming behavior implies the equilibrium relations such as

$$x_t = E_t x_{t+1} - \sigma(i_t - E_t \pi_{t+1} - r_t^n), \tag{4.1}$$

$$r_t^n = \sigma^{-1} g_t, \tag{4.2}$$

$$g_t = \rho_g g_{t-1} + \varepsilon_{g,t}, \tag{4.3}$$

where x_t is the output gap, E_t is the expectation operator conditional on private agents' period t information set, $\sigma > 0$ denotes the intertemporal elasticity of substitution in consumption, i_t is the nominal interest rate set by the central bank, π_t is the inflation rate, r_t^n is the natural rate of interest and g_t is a demand shock which follows an AR(1) process with a persistence coefficient $\rho_g \in (-1, 1)$ and a white noise disturbance $\varepsilon_{g,t}$ with a variance σ_g^2.

On the other hand, profit-maximizing price setting behavior by the firms leads to a forward-looking Phillips curve such as

$$\pi_t = \beta E_t \pi_{t+1} + \kappa x_t, \tag{4.4}$$

where $\beta \in (0,1)$ is a discount factor and $\kappa > 0$ is given by

$$\kappa = \kappa_u(\omega + \sigma^{-1}) = \frac{(1-\alpha)(1-\alpha\beta)}{\alpha(1+\omega\theta)}(\omega + \sigma^{-1})$$

with $\alpha \in (0,1)$ denoting the share of firms keeping prices unchanged in a given period, $\omega > 0$ the inverse of the labor-supply elasticity, $\theta > 1$ the price elasticity of demand for differentiated goods.

The central bank is assumed to have a loss function defined as

$$L_t = E_t \sum_{i=0}^{\infty} \beta^{t+i}(\pi_{t+i}^2 + \lambda x_{t+i}^2), \tag{4.5}$$

where $\lambda = \frac{\kappa}{\theta}$. As shown in Woodford [94], such function is proportional to a second-order approximation to the household's utility function. In this chapter, we assume that the central bank does not have a commitment technology and conducts a discretionary policy. Each period t, the central bank chooses the inflation rate π_t, the output gap x_t, and the nominal interest rate i_t in order to minimize (4.5) subject to the equilibrium conditions (4.1)-(4.4) and the ZLB constraint

$$i_t \geq 0, \tag{4.6}$$

with taking the private agents' expectations as given.

The structural parameters are calibrated using the values from Eggertsson and Woodford [94]. The parameters of the natural rate and demand shock are chosen to be consistent with Nakov [63]. All settings are summarized in Table **??**.

4.3 Optimal policy without uncertainty

In this section, we characterize the optimal discretionary policy without uncertainty as a benchmark for a later section. Non-existence of endogenous state variables in our model allows us to cast the problem of discretionary optimization as a sequence of static problems, even with the ZLB constraint. The period t Lagrangian is given by

$$\begin{aligned}\frac{1}{2}(\pi_t^2 + \lambda x_t^2) &+ \phi_{1t}(x_t - E_t x_{t+1} + \sigma(i_t - E_t \pi_{t+1} - r_t^n)) \\ &+ \phi_{2t}(\pi_t - \beta E_t \pi_{t+1} - \kappa x_t) \\ &- \phi_{3t} i_t,\end{aligned} \tag{4.7}$$

where ϕ_{1t} is the Lagrange multiplier associated with (4.1), ϕ_{2t} with (4.4), and ϕ_{3t} with (4.6). The Kuhn-Tucker conditions for this problem can be written as

$$\begin{aligned}\pi_t + \phi_{2t} &= 0, \\ \lambda x_t + \phi_{1t} - \kappa x_t &= 0, \\ \sigma \phi_{1t} - \phi_{3t} &= 0, \\ i_t \phi_{3t} &= 0,\ i_t \geq 0,\ \phi_{3t} \geq 0.\end{aligned}$$

Markov-Perfect equilibrium in the model can be obtained by summarizing the above conditions.

Figure 4.1 shows the annualized endogenous variables in the equilibrium with each level of natural rate. The solid and dotted line represent the case with and without considering the ZLB constraint, respectively. In Figure 4.1, the zero nominal rate policy is started with a mild negative demand shock which makes the natural rate be lower than the steady state value (3%) but still positive. If the ZLB is ignored or is perfectly foresighted, the central bank should keep interest rate equal to the natural rate level in such a situation. In contrast, with the stochastically binding ZLB constraint, it starts the zero intereset policy earlier than the natural rate falls into the negative area. At the same time, as pointed out in Adam and Billi [1] and Nakov [63], the optimal inflation rate chosen by the central bank becomes below target (0% in this case) with the ZLB concern. Figure 4.1 shows that at the area with the natural rate slightly lower than the steady state value (3%), the inflation rates are kept negative while the output gaps are chosen to be positive. The phenomena is referred to as “deflationary bias” in Nakov [63].

The intuition of the deflationary bias is the following. As shown in Figure 4.1, output and inflation become negative once the ZLB constraint binds, which implies large enough negative shocks constrain the central bank that it cannot fully offset the shocks and allows the economy to run into a liquidity trap. The private agents know this fact. Then the possibility of reaching the lower bound in the future causes them to reduce their expectations of future inflation before the constraint binds. For the central bank, the reduction in expected inflation is isomorphic to a negative cost-push shock which shifts down the intercept of the Phillips curve. Against such negative cost-push shocks, the central bank reacts by letting inflation fall and output rise, which results in the deflationary bias. In summary, the publicly known inability of the monetary policy to avoid a liquidity trap inevitably support the inflation rate below the target in the equilibrium.

4.4 Optimal policy with uncertainty

4.4.1 Uncertainty about intertemporal elasticity of substitution

We now consider the central bank's uncertainty about parameters of the model and its effect on the optimal discretionary policy with the ZLB constraint. Here we focus on uncertainty about the the intertemporal elasticity of substitution, σ. The reason for our focus on the parameter is twofold. First, the value of parameter is significant for the central bank's decision in the face of a liquidity trap. In particular, it determines the size of output contraction and the effectiveness of the monetary policy in such a situation. A larger (smaller) value of σ implies a higher (lower) degree of real interest sensitivity of aggregate demand, which results in more (less) serious contraction with the higher real rate caused by the ZLB constraint, at the same time, stronger (weaker) effects of interest rate or inflation expectations control by the central bank. The ignorance about the size of σ makes it harder for the bank to judge how deep a downturn of the economy will be and how long it should keep the interest rate lower to recover the economy. Second, in reality, there exists great uncertainty about the parameter σ. The key importance of the size of parameter has been recognized and estimated by hundreds of researcher to date. However, depending on sample selection (periods, micro or aggregate data, countries) or estimation techniques, a wide range of values have been reported in the literature.[4] Corresponding to this fact, a variety of calibration patterns are employed such as 6.25 in Rotemberg and Woodford [72] to 0.2 in Nakov [63]. For now, there is still no consensus about the true value of σ and considering the uncertainty about it is reasonable.

[4]About the range of estimated values of σ, see Havrànek [34] and Havrànek et al. [35]for example.

In our setting, the central bank and private agents have basically the same information set. They are assumed to know the current values of the inflation rate π_t, the output gap x_t, and the demand shock g_t. They also know that the private agents' expectations are formed with (4.1)-(4.4). Only exception is the value of the parameter σ, which private agents know but the bank doesn't. Because of this parameter uncertainty, the bank has less information than private agents and cannot observe their expected inflation $E_t\pi_{t+1}$ and output gap $E_t x_{t+1}$.

In the face of this uncertainty, the central bank puts a probability distribution of the elasticity σ with a mean $\bar{\sigma} > 0$ and a variance v_σ. The uncertainty here propagates not only to the coefficient σ in IS equation (4.1), but also the natural rate r_t^n in (4.2), the coefficeint κ of NKPC in (4.4) and the output gap weight λ in the loss function (4.5). Then the central bank's expectations of private agents' equations (4.1)-(4.4) conditional on its information set are given by

$$x_t = E_t^{CB} x_{t+1} - \bar{\sigma}(i_t - E_t^{CB}\pi_{t+1}) + \bar{\sigma}\beta^{-1}\left\{\bar{\kappa} - \kappa_u(\omega + \sigma^{-1})\right\} x_t + g_t, \tag{4.8}$$

$$\pi_t = \beta E_t^{CB}\pi_{t+1} + \bar{\kappa} x_t, \tag{4.9}$$

where E_t^{CB} is the expectation operator conditional on the central bank's period t information set, $\bar{\sigma}$ and $\bar{\kappa}$ denote the bank's expectations of σ and κ based on its probability distribution of σ, respectively. In a similar fashion, taking the bank's expectations of the loss function (4.5) yields

$$
\begin{aligned}
E_t^{CB}[L_t] = \pi_t^2 + \bar{\lambda} x_t^2 + \beta(V_t^{CB}[\pi_{t+1}] + \bar{\lambda} V_t^{CB}[x_{t+1}]) \\
+ E_t^{CB} \sum_{i=1}^{\infty} \beta^{t+i} \left\{ (E_{t+i-1}^{CB} \pi_{t+i})^2 + \bar{\lambda}(E_{t+i-1}^{CB} x_{t+i})^2 \right. \\
\left. + \beta(V_{t+i}^{CB}[\pi_{t+i+1}] + \bar{\lambda} V_{t+i}^{CB}[x_{t+i+1}]) \right\} ,
\end{aligned}
\tag{4.10}
$$

where V_t^{CB} is the variance operator conditional on the bank's period t information set and $\bar{\lambda}$ denotes the bank's expectations of λ. It is important to note that the expected loss $E_t^{CB}[L_t]$ depends on not only the future deviations of the expected goal variables from their targets $((E_t^{CB}\pi_{t+1})^2$ and $(E_t^{CB}x_{t+1})^2)$, but also future variances of inflation and the output gap given by

$$
V_t^{CB}[\pi_{t+1}] = v_\kappa \beta^{-1} x_t^2 + t.i.p., \tag{4.11}
$$

$$
V_t^{CB}[x_{t+1}] = v_\sigma \beta \lambda \left\{ i_t - \beta^{-1}(\pi_t - \kappa_u \omega x_t) \right\}^2 + t.i.p., \tag{4.12}
$$

where v_σ and v_κ are the variances of σ and κ based on the bank's probability distribution of the uncertain parameter, respectively and "$t.i.p.$" denotes terms independent of policy. When the value of parameter σ is known (i.e., $v_\sigma = v_\kappa = 0$), these conditional variances are independent of the state of the economy and monetary policy is independent of the degree of uncertainty in the economy. In contrast, when some parameters are uncertain, the conditional variances of the inflation rate and output gap depend on the state of the economy, so they are not independent of monetary policy. For example, (4.11) implies that the conditional variances of the future inflation rate $V_t^{CB}[\pi_{t+1}]$ depends on the level of output gap in the current period x_t, so monetary policy can affect $V_t^{CB}[\pi_{t+1}]$

through controlling x_t. With uncertainty of model parameters, the central bank seek the monetary policy to reduce the deviation of the endogenous variables from the target as usual, but at the same time, not to amplify the future variabilities of them so much.

Each period t, the central bank chooses π_t, x_t, i_t in order to minimize (4.10) subject to (4.8), (4.9), (4.11), (4.12) and the ZLB constraint (4.6). The period t Lagrangian is given by

$$
\begin{aligned}
&\frac{1}{2}(\pi_t^2 + \bar{\lambda} x_t^2 + v_\kappa \beta^{-1} x_t^2 + v_\sigma \beta \lambda \left\{ i_t - \beta^{-1}(\pi_t - \kappa_u \omega x_t) \right\}^2) \\
&\qquad + \phi_{1t}(x_t - E_t^{CB} x_{t+1} + \bar{\sigma}(i_t - E_t^{CB}\pi_{t+1}) - \bar{\sigma}\beta^{-1}\left\{ \bar{\kappa} - \kappa_u(\omega + \sigma^{-1}) \right\} x_t - g_t) \\
&\qquad + \phi_{2t}(\pi_t - \beta E_t^{CB}\pi_{t+1} - \bar{\kappa} x_t) \\
&\qquad - \phi_{3t} i_t, \qquad (4.13)
\end{aligned}
$$

and the Kuhn-Tucker conditions for this problem can be written as

$$\pi_t + \phi_{2t} - \bar{\lambda} v_\sigma \left\{ i_t - \beta^{-1}(\pi_t - \kappa_u \omega x_t) \right\} = 0, \qquad (4.14)$$

$$
\begin{aligned}
&\bar{\lambda} x_t + \left[1 - \bar{\sigma}\beta^{-1} \left\{ \bar{\kappa} - \kappa_u(\omega + \sigma^{-1}) \right\} \right] \phi_{1t} - \bar{\kappa}\phi_{2t} \\
&\qquad + v_\kappa \beta^{-1} x_t + \bar{\lambda} v_\sigma \kappa_u \omega \left\{ i_t - \beta^{-1}(\pi_t - \kappa_u \omega x_t) \right\} = 0, \qquad (4.15)
\end{aligned}
$$

$$\bar{\sigma}\phi_{1t} - \phi_{3t} + \beta \bar{\lambda} v_\sigma \left\{ i_t - \beta^{-1}(\pi_t - \kappa_u \omega x_t) \right\} = 0, \qquad (4.16)$$

$$i_t \phi_{3t} = 0, \;\; i_t \geq 0, \;\; \phi_{3t} \geq 0. \qquad (4.17)$$

These conditions and private agents' equations (4.1)-(4.4) leads to the Markov-Perfect equilibrium in this case. Figure 4.2 compares realized endogenous variables in the equilibriums with and without uncertainty about the parameter σ. About the probability distribution which bank holds about σ, we set $\bar{\sigma} = 0.5$ and consider three cases as

$v_\sigma = 0, 0.1, 0.2$. Corresponding to these values, the other parameters such as $\bar{\kappa}$, $\bar{\lambda}$, and v_κ are determined. The other parameters follow the setting in Table **??**.

In the figure, the bold and thin solid line shows the case with $v_\sigma = 0.2$ and 0.1, respectively. As in the result in the previous section, the central bank starts the zero interest rate policy even when the natural rate is still positive. However, the area of zero interest rate policy becomes narrower with uncertainty about σ. This implies the delayed nominal rate cut in the recession and the earlier liftoff in the recovery phase of the economy. The optimal policy is less aggressive compared to the case without uncertainty (i.e., $v_\sigma = 0$), which is depicted as the dashed line. In addition to this, in the ZLB territory, the realized inflation rates are higher than the no-uncertainty case while the output gaps are almost the same. In the area with the natural rate slightly lower than the steady state level (3%), the central bank does not sacrifice inflations so aggressively as it does in the no-uncertainty case and get just mildly positive output gaps. In other words, the deflationary bias, which is the key phenomena of discretionary policy facing the ZLB constraints, caused by the absence of committing device of the central bank, deteriorates with parameter uncertainty. As the figure shows, these tendencies become stronger as uncertainty the central bank faces about σ increases.

The key to understand the results here is the trade-off between the inflation rate and the output gap the central bank faces. When the bank has uncertainty about the parameter σ, it has to concern about the future variances of the inflation rate and the output gap, $V_t^{CB}[\pi_{t+1}]$ and $V_t^{CB}[x_{t+1}]$. As shown in (4.11) and (4.12), the both of them increase with the level of current output gap and the latter decreases with the level of current inflation rate. Because of this, the central bank hesitates to accept lower inflation in return for output boom when the shocks generating short-run trade-off between the two variables occur. If the private agents know this fact (as the setting here), they expect that against the reduction of their inflation expectations caused by the anticipation of future ZLB episodes, the central bank's reaction of letting inflation fall and output rise will be much milder than would be in the case without uncertainty. This suppresses the downward pressure for the inflation expectations, which raises the actual inflation rate through the NKPC equation (4.9). In other words, the expectation that the central bank obey the Brainard principle, i.e., respond less aggressively to shocks, deteriorates the deflationary bias. In consistent with this expectation, in the equilibrium, the central bank chooses the less aggressive reduction of interest rates and earlier monetary tightening compared to the case without parameter uncertainty. Figure 4.3 plots the impulse responses to a a large negative shock to the natural real rate with and without σ uncertainty. The figure shows the earlier liftoff of nominal interest rate, higher inflation, and lower output gap, which are in line with the intuition above.

4.4.2 Uncertainty about inflation persistence

Next, we examine how uncertainty about inflation persistence changes the optimal monetary policy. In this regard, we extend the basic model as considering a rule of thumb pricing firm á la Amato and Laubach [2]. As the basic model, in each period, a fraction α of firms are unable to re-set their prices. In addition to this, now the remaining $1-\alpha$ firms will be able to re-optimize with probability ϕ, and with probability $1-\phi$ they will follow the simple pricing rule, which sets their prices equal to the mean of all firms' prices set in the previous period. In this setting, pricing behavior by the firms results in the Hybrid Phillips curve such as

$$\pi_t = \gamma_b \pi_{t-1} + \gamma_f E_t \pi_{t+1} + \gamma_k \kappa x_t, \tag{4.18}$$

where

$$\gamma_b = \frac{1-\phi}{\alpha + (1-\phi)\left\{1-\alpha(1-\beta)\right\}},$$
$$\gamma_f = \frac{\alpha\beta}{\alpha + (1-\phi)\left\{1-\alpha(1-\beta)\right\}},$$
$$\gamma_\kappa = \frac{\alpha\phi}{\alpha + (1-\phi)\left\{1-\alpha(1-\beta)\right\}}.$$

As derived in Amato and Laubach [2], the loss function based on the second-order approximation of household's welfare can be written as

$$L_t = E_t \sum_{i=0}^{\infty} \beta^{t+i} \left\{ \pi_{t+i}^2 + \lambda_x x_{t+i}^2 + \lambda_{\Delta\pi} (\pi_{t+i} - \pi_{t+i-1})^2 \right\},$$

where the weight on the deviation of output gap and changes in inflation from each target is

$$\lambda_x = \frac{\kappa}{\theta}, \quad \lambda_{\Delta\pi} = \frac{1-\phi}{\alpha\phi},$$

respectively.

Here we consider uncertainty about the parameter ϕ, which makes γ_b, γ_f, γ_κ and $\lambda_{\Delta\pi}$ be uncertain at the same time. As in the previous sub-section, the central bank is assumed to put a probability distribution of ϕ with a mean $0 < \bar{\phi} < 1$ and a variance

v_ϕ. In the period t, the central bank tries to minimize

$$\pi_t^2 + \lambda_x x_t^2 + \bar{\lambda}_{\Delta\pi}(\pi_t - \pi_{t-1})^2 \tag{4.19}$$

$$+ \beta \left\{ \lambda_{\Delta\pi}(E_t^{CB}[\pi_{t+1} - \pi_t])^2 + V_t^{CB}[\pi_{t+1}] + \lambda_x V_t^{CB}[x_{t+1}] + \bar{\lambda}_{\Delta\pi} V_t^{CB}[\pi_{t+1} - \pi_t] \right\}, \tag{4.20}$$

subject to

$$x_t = E_t^{CB} x_{t+1} - \sigma(i_t - E_t^{CB}\pi_{t+1}) + g_t$$

$$\pi_t = \bar{\gamma}_b \pi_{t-1} + \bar{\gamma}_f E_t^{CB}\pi_{t+1} + \bar{\gamma}_k \kappa x_t$$

$$V_t^{CB}[\pi_{t+1}] = v_\phi \beta^{-2} \left\{ (\alpha^{-1} - 1 + \beta)\pi_t - \alpha^{-1}\pi_{t-1} + \kappa x_t \right\}^2 + t.i.p.,$$

$$V_t^{CB}[x_{t+1}] = \sigma^{-2} V_t^{CB}[\pi_{t+1}] + t.i.p.,$$

$$i_t \geq 0,$$

where $\bar{\lambda}_{\Delta\pi}$ is the expected value of $\lambda_{\Delta\pi}$ based on the subjective distribution of the central bank. As in the case with σ uncertainty, the central bank now has to concern about the future variances of the inflation rate ($V_t^{CB}[\pi_{t+1}]$), the output gap ($V_t^{CB}[x_{t+1}]$), and the changes in inflation rate ($V_t^{CB}[\pi_{t+1} - \pi_t]$). The Markov perfect equilibrium conditions in this setting can be written as

$$
\begin{aligned}
&x_t - E_t x_{t+1} + \sigma(i_t - E_t\pi_{t+1} - \sigma^{-1} g_t) = 0,\\
&\pi_t - \gamma_b \pi_{t-1} - \gamma_f E_t \pi_{t+1} - \gamma_k \kappa x_t = 0,\\
&\pi_t + \bar{\lambda}_{\Delta\pi}(\pi_t - \pi_{t-1}) - \beta\lambda_{\Delta\pi}(E_t^{CB}\pi_{t+1} - \pi_t) + \phi_{2t} - \beta\bar{\gamma}_b E_t^{CB}\phi_{2t+1}\\
&\quad + v_\phi \beta^{-1}(1 + \lambda_{\Delta\pi} + \lambda_x \sigma^{-2})(\alpha^{-1} - 1 + \beta)\left\{(\alpha^{-1} - 1 + \beta)\pi_t - \alpha^{-1}\pi_{t-1} + \kappa x_t\right\}\\
&\quad - v_\phi \alpha^{-1}(1 + \lambda_{\Delta\pi} + \lambda_x \sigma^{-2})(\alpha^{-1} - 1 + \beta)\left\{(\alpha^{-1} - 1 + \beta)E_t^{CB}\pi_{t+1} - \alpha^{-1}\pi_t + \kappa E_t^{CB} x_{t+1}\right\} = 0\\
&\lambda_x x_t + \phi_{1t} - \bar{\gamma}_\kappa \kappa \phi_{2t} + v_\lambda \kappa \beta^{-1}(1 + \lambda_{\Delta\pi} + \lambda_x \sigma^{-2}) \cdot \left\{(\alpha^{-1} - 1 + \beta)\pi_t - \alpha^{-1}\pi_{t-1} + \kappa x_t\right\} = 0,\\
&\bar{\sigma}\phi_{1t} - \phi_{3t} = 0, \quad i_t \phi_{3t} = 0, \quad i_t \geq 0, \quad \phi_{3t} \geq 0.
\end{aligned}
$$

In numerical simulation, we assume that the central bank's subjective distribution about ϕ is based on the Beta distribution. As pointed out in Kimura and Kurozumi [41], in this setting, the expectation of loss functional weight on the variability of inflation changes can be written as

$$
\bar{\lambda}_{\Delta\pi} = \frac{(1 - \bar{\phi})\left\{\bar{\phi}(1 - \bar{\phi}) - v_\phi\right\}}{\alpha\left\{\bar{\phi}^2(1 - \bar{\phi}) - v_\phi(1 + \bar{\phi})\right\}}
$$

We set $\bar{\phi} = 0.75$ and consider three cases as $v_\phi = 0, 0.025, 0.05$. The other parameters follow the setting in Table **??**.

Figure 4.4 compares realized endogenous variables in the equilibriums with and without uncertainty about the parameter ϕ. In the figure, the bold and thin solid line shows the case with $v_\phi = 0.05$ and 0.025, respectively. In both cases, the realized inflation rates are lower than the no-uncertainty case (i.e., $v_\phi = 0$) depicted as the dashed line. At the same time, with large uncertainty about inflation persistence, the realized output gap sharply declines in the area with the negative natural interest rate. On the other hand, in the area with the positive natural rate, the realized output gap is higher than that of no uncertainty case. These observations imply that with uncertainty about inflation persistence, the central bank conducts more aggressive monetary policy against the reduction of private agents' inflation expectations, which is caused by the anticipation of future ZLB episodes. When the central bank has uncertainty about the parameter ϕ, it has to concern about the new trade-off between the inflation and output gap, which is added by the future variances of the inflation rate ($V_t^{CB}[\pi_{t+1}]$), the output gap ($V_t^{CB}[x_{t+1}]$), and the changes in inflation rate ($V_t^{CB}[\pi_{t+1} - \pi_t]$). These variances depend positively on the current inflation, output gap and the variability of inflation rate. In addition, as uncertainty about ϕ increases, the expected weight on the variability of inflation $\bar{\lambda}_{\Delta\pi}$ also increases. This decreases the relative weight on the output gap deviation from the target. In such a situation, the central bank willingly accepts lower inflation and higher output gap against the negative cost-push shock. If the private agents know this fact, they expect that against the reduction of their inflation expectations, the central bank's reaction will be more aggressive than would be in the case without uncertainty and this boosts the downward pressure for the inflation expectations, which decreases the actual inflation rate through the NKPC equation (4.18). As a result, uncertainty about inflation persistence makes the central bank to delay the liftoff from the zero interest rate policy, which is opposed to the result in the case with uncertain σ. Figure 4.5, which shows the impulse responses to a large negative shock to the natural real rate with and without ϕ uncertainty, is consistent with the intuition above.

4.5 Conclusion

In this chapter, we theoretically analyze the optimal discretionary policy with the stochastic ZLB constraint with parameter uncertainty. We focus on the central bank who faces uncertainty about the intertemporal elasticity of substitution and inflation persistence. Depending on the form of parameter uncertainty, the optimal policy with the zero lower bound concern crucially changes. In particular, with uncertainty about the intertemporal elasticity of substitution, the zero interest rate policy is started belatedly and terminated earlier, or in other words, less aggressive compared to the case without uncertainty. In contrast, uncertainty about inflation persistence makes the central bank hurry the start of zero interest rate policy and delay the liftoff from it.

The key to understand the results is the new trade-off between the inflation rate and the output gap with parameter uncertainty. Depending on whether this trade-off recommends the central bank to conduct more or less aggressive policy against the reduction of private agents' inflation expectations, the optimal length of zero interest policy will change.

Structural Parameters		
Discount Factor	β	0.99
Intertemporal elasticity of substitution in consumption	σ	0.5
Inverse of labor supply elasticity	ω	0.47
Price elasticity of demand	θ	10
Share of firms keeping prices unchanged	α	0.8106
Shock process		
Steadey state value of natural rate (% per Annum)	$\bar{r}_t^n$	3
AR-coefficient of demand shocks	ρ_g	0.65
S.d. of demand shock innovations (annual)	σ_g	1.86

Table 4.1: Baseline Calibration

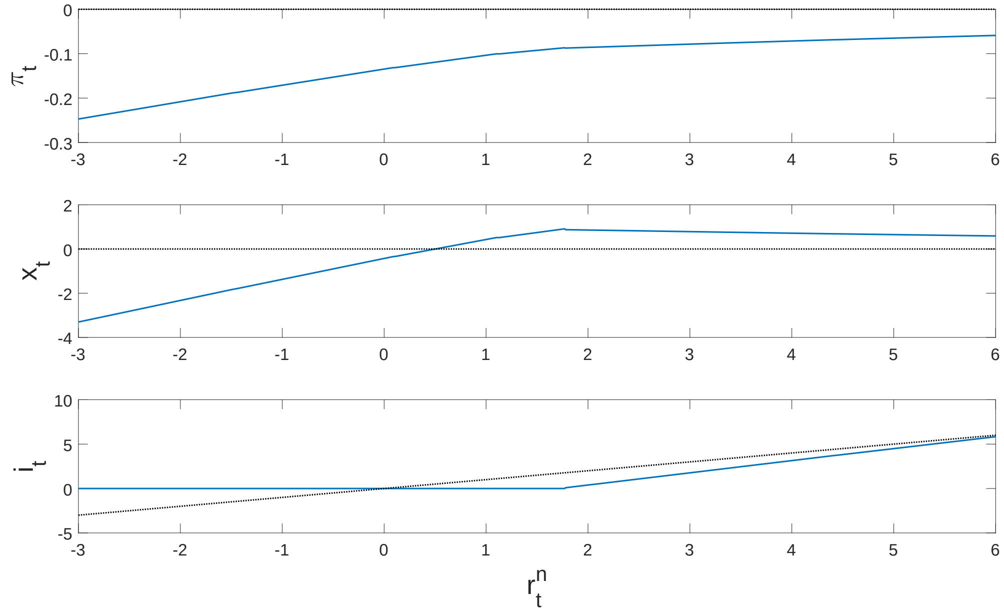

Fig. 4.1: Optimal Discretionary Policy without uncertainty

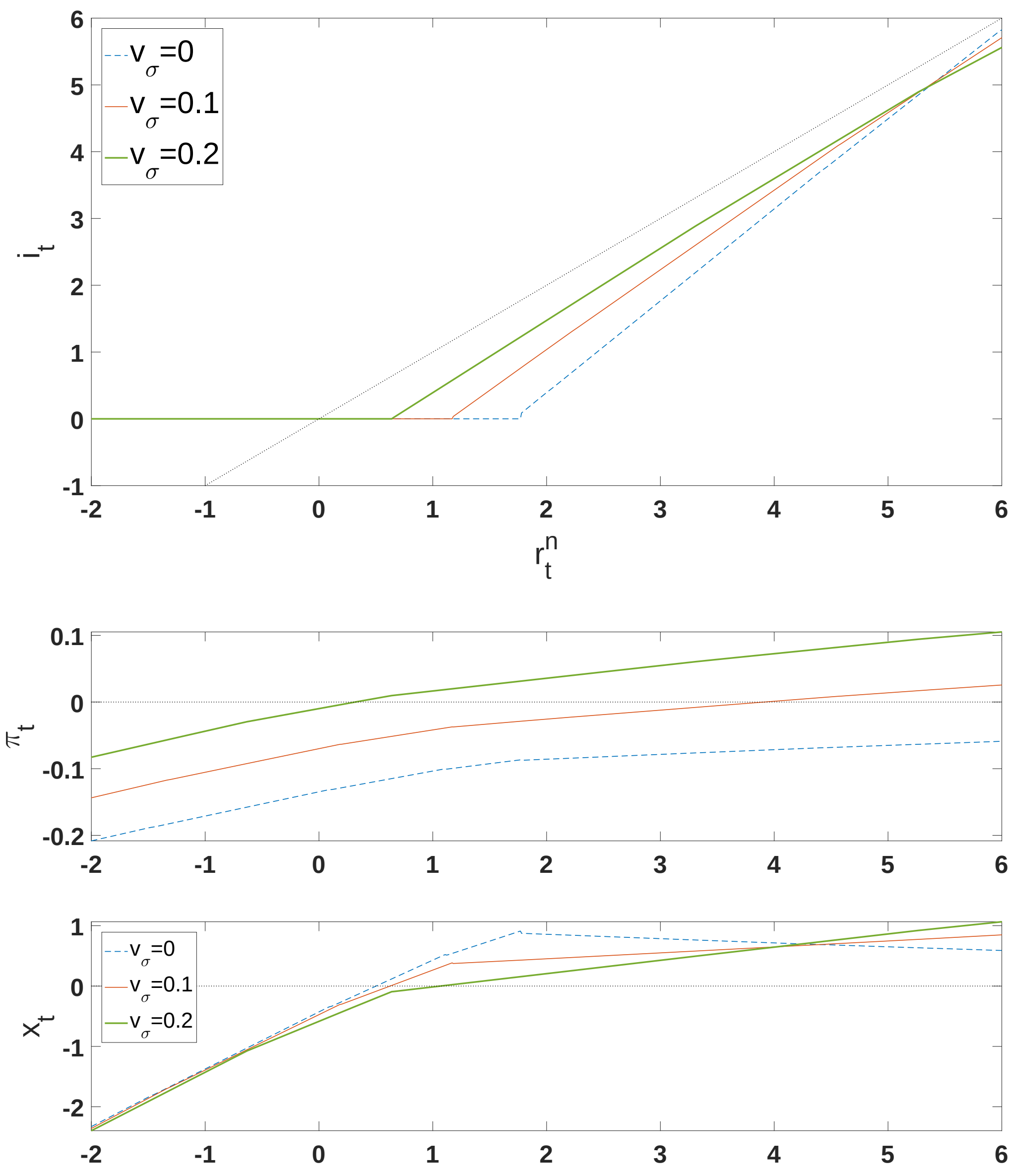

Fig. 4.2: Optimal Discretionary Policy with and without σ uncertainty

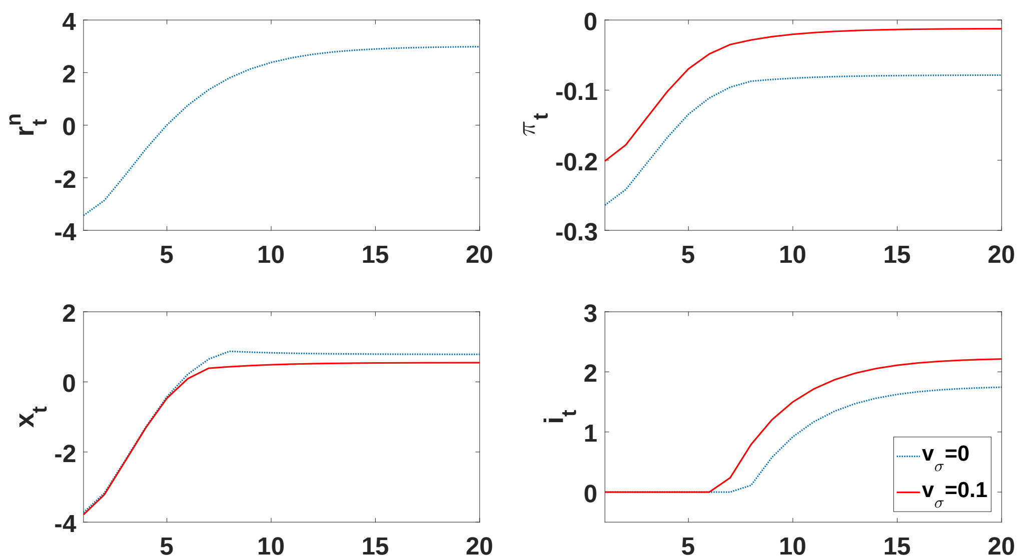

Fig. 4.3: Impulse Responses to a Large Shock with and without σ uncertainty

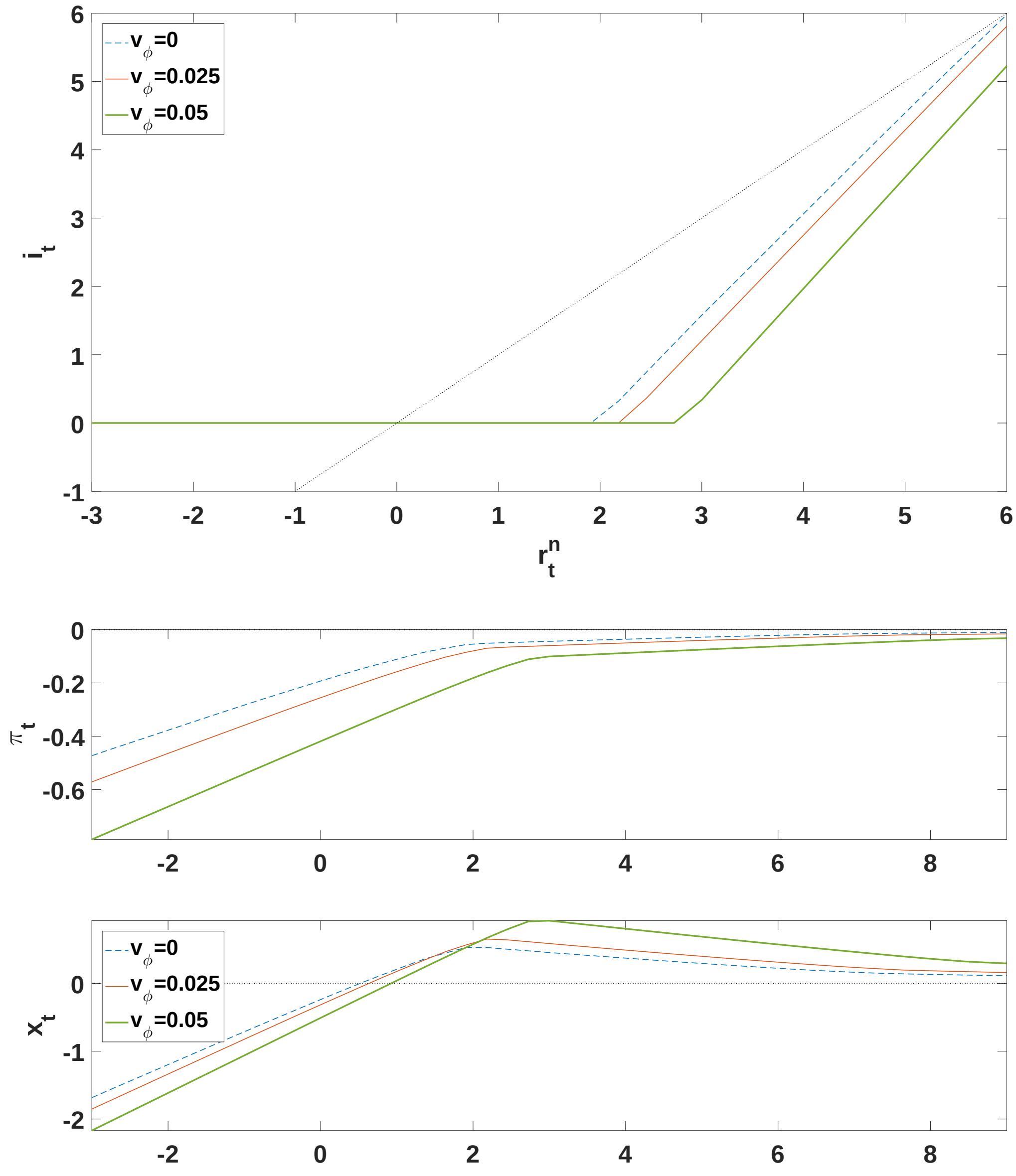

Fig. 4.4: Optimal Discretionary Policy with and without ϕ uncertainty

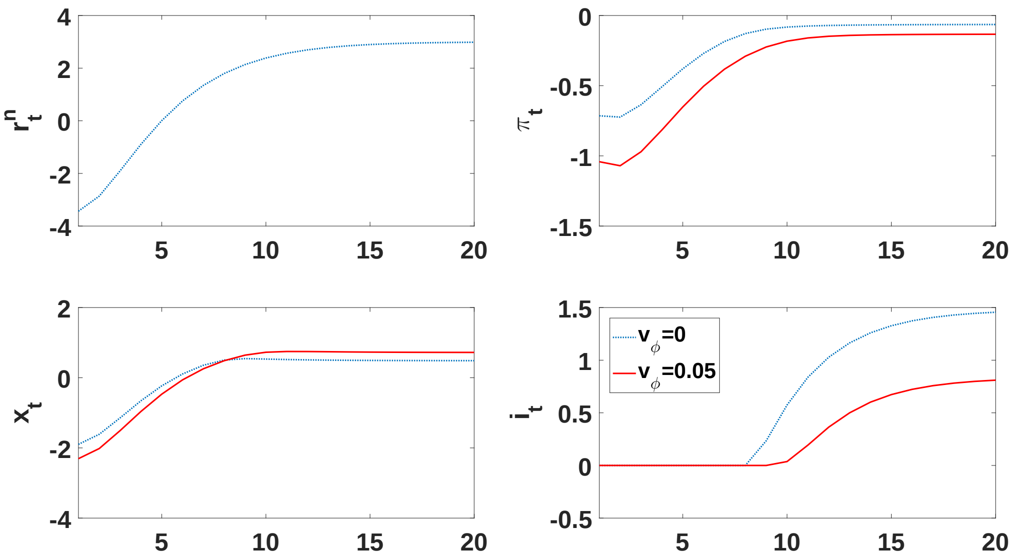

Fig. 4.5: Impulse Responses to a Large Shock with and without ϕ uncertainty

Chapter 5

General Conclusions and Discussion

It has been almost six years since the Quantitative and Qualitative Easing was introduced by the Bank of Japan. This dissertation has tried to shed light on what this epoch-making, extremely aggressive and bold monetary easing framework has brought about to the Japanese economy by both the empirical and theoretical perspectives. In the final chapter here, we first summarize the findings by the three subjects and try to give an assessment of QQE based on them: (i) Long-run inflation expectations, (ii) Phillips curve and medium-short horizons inflation expectations, (iii) Optimal monetary policy and communication under uncertainty. Then the final subsection points out some limitations of our research and suggests some future tasks.

5.1 Summary of findings and discussion

5.1.1 Long-run inflation expectations

In Chapter 2, we investigate how the introduction of QQE causes the cross-sectional and time changes of the long-run inflation expectations in Japan. Our estimation suggests that cross sectional dispersion of long-run inflation expectations are large before the introduction of QQE in April 2013. In contrast, after the introduction, the estimated long-run inflation expectations are massed around the level of 1%. This implies that

QQE by the BOJ succeeds to anchor the inflation expectations of the private agents in Japan, while the anchored level is significantly lower than the target level, 2%. At the same time, our result also suggests that the long-run inflation expectations of the private agents rise sharply soon after the introduction of QQE and after that, have been moderately decaying until now.

These findings imply that the effect of QQE itself for raising the inflation expectations is relatively weak and short-lived than the BOJ had initially expected. According to this concern, it seems that the next task for the BOJ is to suggest the new policy framework, which tries to head off the decay of long-run inflation expectations.

5.1.2 Phillips curve and medium-short horizons inflation expectations

Chapter 3 examines the change of medium to short horizons inflation expectations by estimating the expectation-level Phillips curve. The estimation results basically imply that the relationship between expected output and expected inflation in Japan has recovered in recent periods. While the estimated anchor of inflation expectations rises significantly soon after the introduction of QQE, both medium and short term anchor starts to decline at the latest in 2016 and have been stable at 0.5% in recent years. These findings can be said both good news and bad news for the future conduct of the monetary policy by the BOJ. The strong relationship between the output and inflation in the expectation formation of private agents suggests that the BOJ can raise their inflation forecast relatively easily by making them believe that the future output growth will steadily increase. However, at the same time, the low anchor of inflation expectations, especially in the short horizons forecasts, may drag on the policy effect. The decline of anchor in recent years partly implies that the credibility of the commitment by the BOJ is damaged by repeated delay of achievement of 2% inflation target and downward revision of inflation forecast.

Another concern is that the sensitiveness of inflation forecasts to the supply shocks term, especially the expectations for the change of oil price, becomes larger in recent periods. To mitigate the disturbing effect of it, the BOJ should clearly report its outlook of the oil price or another supply shock factors as possible and when these factors show the sign of negative effect on the inflation expectations, announce the policy strategy to deal with them as soon as possible. More clearer and accurate outlook for the economy may recover the credibility of the BOJ's future policy and lead to the stable anchor of medium to short-run inflation expectations.

5.1.3 Optimal monetary policy and communication under uncertainty

Chapter 4 theoretically assesses the property of the optimal policy when the central bank faces both the zero lower bound of nominal interest rate and uncertainty about the transmission mechanism or inflation dynamics at the same time. When the commitment of the monetary policy expressed in the forward guidance by the central bank is not credible, the future possibility of a liquidity trap situation lowers the inflation expectations of private agents in the economy even if the nominal interest rate is positive at this time. This leads to actually lower inflation realization, which is the phenomena reffered to the deflationary bias.

Our analysis suggests that if the central bank faces the policy effect uncertainty and deal with it by seeking the robustness for the policy against the uncertainty, and if the private agents know this fact, the deflationary bias will deteriorate. This result implies that by clearly telling what the central bank knows and doesn't know about the transmission mechanism of its policy to the private agents, the monetary policy expectations of private agents will be stable and improve. At least against uncertainty about the transmission mechanism and the strength of the monetary policy effect, to increase the transparency will benefit the central bank to raise the inflation rate from the level below the target. In contrast, if the inflation dynamics is the source of uncertainty, our model suggests that the central bank should choose more aggressive policy and make the zero interest rate policy longer. In this case, the deflationary bias will become more severe and the realized inflation tends to be below the central bank's target even though the mild output boom happens.

Our results in Chapter 2 and Chapter 3 imply the strong dependence of inflation expectations on the already realized inflation rate. The sum of estimated AR coefficient in the monthly inflation forecast model is about 0.9. The coefficient on the shortest horizon inflation forecast in the expected hybrid Phillips curve is above 0.5 in most cases. In the *Comprehensive Assessment* of QQE in September 2016, the BOJ admitted that "expectations formation in Japan is largely adaptive, that is, backward-looking" and "a further rise in inflation expectations through the adaptive mechanism is uncertain and may take time". One interpretation of this fact is that the BOJ has faced uncertainty about the relation of inflation expectations and realized inflation dynamics. According to our model, the central bank should take aggressive monetary policy like QQE under such uncertainty. In that sense, it seems that our model well captures Japan's experience in the recent years.

5.2 Limitations of the research and future issues

5.2.1 Whose inflation expectations should we care about?

In Chapter 2 and 3, we use *ESP Forecast* data to evaluate the effect of BOJ's QQE policy on the formation of inflation expectations. As explained earlier, *ESP Forecast* collects the monthly forecasts reported by the economists in Japan, who directly participate financial market and observe a wide variety of financial indicators in their daily lives. In that sense, our estimation results should represent inflation expectations by relatively more "informed" agents.

There are several good reasons for this strategy. Indeed, central bank communications often focus on participants of financial markets. How financial markets perceive the path of future monetary policy strogly and quickly affects financial indicators such as long-term interest rates, so it provides a direct transmission mechanism of monetary policy actions. Given that thier predictions must be the important policy tools for central bank and the QQE policy actually includes communication strategies such as storong commitments by the BOJ Governor Haruhiko Kuroda, it is reasonable to focus on the inflation expectations of professional forecasters or financial market participants. In addition to this, if the expectations of different agents such as households, firms, and professional forecasters are not so different as the standard macroeconomic models assume, then our results must contain sufficient information about the level or movement of average inflation expectations of the private agents in Japan.

However, several studies point out that inflation expectations of households and firms may have quite different features compared to those of professional forecasters (see, for example, Armantier et al. [3], Coibion et al. [14], Kumar et al. [46], Mankiw et al. [53]). Mankiw et al. [53] and Coibion et al. [14] report that US households and firms are inattentive to aggregate or "macroeconomic" inflation dynamics, but more attentive to "microeconomic" change of the good prices which they frequently observe, such as food or gasoline prices. Due to high volatility of those prices and heterogeneity of people's consumption baskets, disagreement about future inflation among households is much larger than that among professional forecasters. Coibion et al. [14] also report that US households and firms tend to make higher inflation forecasts compared to professional forecasters.

These studies indicate that household and firms inflation expectations may deviate systematically from the expectations of professional forecasters. The future research is needed whether this holds in Japan and their information gives us another implication for the evaluation of QQE.

5.2.2 The other transmission mechanism of QQE

Our analysis solely focuses on the inflation expectation channel of the unconventional monetary policy. Chapter 2 and 3 examine how the introduction of QQE made change in the level or heterogeneity of inflation expectations. Chapter 4 considers the effect of model uncertainty with the falling inflation expectations which is caused by the central bank's lack of commitment technology.

As explained in Chapter 1, the reason why we focus on the channel is simply that it is the main transmission mechanism the BOJ emphasized when it introduced QQE. By raising the long-run inflation expectations by the strong commitment and massive monetary easing, the BOJ intended to lower the real interest rates with the expectation that it would increase investment by firms as well as durable goods consumption by households. Then such stimulated aggregate demand would lead to an improvement in the output gap and inflation in Japan.

On the other hand, there was also the other channels QQE might have worked. For example, the BOJ also referred to the "portfolio rebalancing" effect. If QQE succeeds to lower the investment cost of financial institutions or raise asset prices, then it encourages them to change the composition of their portfolios. In particular, by massively purchasing the longer-term JGB from the markets, the BOJ aims to lower the long-term interest rate and make more incentives for financial institutions to reduce their holdings of government bonds and to purchase the assets which is more riskier but with higher expected returns. Then this leads to an increase in a wide range of asset prices, makes financial conditions more accommodative. Yet another transmission channel of the QQE policy is the exchange rate channel. The greater differences in the monetary base and interest rate between Japan and the US are likely to promote a depreciation of the yen, which may improve the output gap by raising exports of goods and services. It may also contribute to raise CPI through imported prices.

Because of our focus on the inflation expectation channel, our analysis is silent about the portfolio rebalancing and the exchange rate channel. Further reseach is needed to evaluate the effect of QQE from the perspective of these transmission mechanism.[1]

[1] About the evaluation of QQE from portfolio rebalancing channel, see Saito and Hogen [76] and Fukunaga et al. [29].

5.2.3 Negative interest rate policy and Yield Curve Control

In February 2016, the BOJ started negative interest rate policy, which adopted a negative interest rate on part of excess reserves. In particular, it newly decomposed the outstanding current account balance of financial institutions into three types: Basic Balance with a positive rate 0.1%, Macro Add-on Balance with 0% rate, and Policy-Rate Balance with a negative rate -0.1%. In september 2016, the BOJ introduced the new policy framework which is called "Quantitative and Qualitative Monetary Easing with Yield Curve Control". In this framework, the BOJ's main operating target was shifted again from monetary base to short-term and long-term interest rates.

In our anlysis, we regard negative interest rate policy and Yield Curve Control as the parts of one monetary easing package, QQE, rather than completely new independent policy frameworks. This is basically consistent with the BOJ's view about these policy frameworks. According to Shirai [79], who is one of the former BOJ Board Member, the two frameworks are "meant to complement and strengthen the past monetary easing practices, rather than replace the previous practices". Indeed, both policies were expected to promote further decline of long-term interest rate and make financial conditions in Japan more accommodative through the interest rate, credit, and portfolio rebalancing channel. In that sense, the expected transmission mechanism of both policies are not much different compared to the contents which the BOJ declared when QQE was started.

Nevertheless, it may be worth treating each framework separately and analyzing the difference of them in more detail. Further studies are needed to estimate the actual cost and benefit of negative interest policy and to examine whether central bank can and should directly control long-term interest rate.

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