Essays on Japan's Macroeconomic Model

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(日本のマクロ経済モデルの推定とその含意に関する研究)

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Shingo Umino

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Chapter 1

Introduction

1.1 Measuring "ability" in macroeconomics

People always have a desire to learn about their "ability" to accomplish tasks in various situations. Moreover, want to meet that desire as often as possible in times of emergency. Herein, "ability" will be used to mean the potential capability that a person has. Demonstrating that "ability" is equivalent to getting that potential capability under the influence of exogenous factors. For example, for students, it shows that they accomplish their best performance when they have a cold. Infrequently, fortunately, they might achieve results that actually exceed their "ability".

When people try to estimate their own power, in the case of entering university, the estimation method is an examination to enter university. The quantified result of examinations is expressed as a "deviation value". After graduating from university, the "ability" is represented as quantified or visualized outcomes from every perspective except the evaluation of "ability" related to study, communication skills and a methodical mind. However, the question remains of whether or not numeric "ability" is valid, in addition to the problem that it is difficult to estimate the "ability" because of the unclear definition of "ability".

Why are people tempted to measure their abilities against others? This is true because the quantified "ability" is efficient information to ascertain the present "ability" of oneself and others. Moreover, we can not obtain any benefit merely by estimating the "ability". If that is so, after learning the "ability", it is important to think of what we should do next. For instance, for high school students, who obtain their ability through examinations, they will be recommended by their teachers to enter universities that are suitable for their level referred to a deviation value. Then they receive the specific steps necessary to improve their performance.

We generally note that people might misread something in the evaluation of “ability” if it is done just one time and using only one method. Therefore, to judge “ability” objectively, it is necessary at least either (1) to possess the prior several results or (2) to possess the present several results obtained by several means.

The story likened to the “ability” of people described above can also be applied to an economy. In this case, the “ability” of the economy, in economic terms, refers to a condition called ”potential” or, in restricting the condition, ”natural”. Because the measured power of humans applies mainly to academic achievement, the “ability” of the economy shown by economics is expressed as the total amount of goods and services produced by the economy in one country. Specifically, gross domestic product (GDP) is used. In addition, in this case, the definition of “ability” is, based upon recent macroeconomic theory, that the output is achieved under conditions in which there is an absence of distortion to the whole economy.

Economists and econometricians frequently seek to assess the “ability” of an economy. In particular, economists involved in policy-making of the government or the central bank generally need to ascertain “ability” quickly and accurately. After estimating the “ability”, they compare it with actual published GDP, and then regard the economy as down in the case in which the actual GDP is much lower than the “ability” and conversely regard the economy as healthy in cases where the actual GDP is much greater than the “ability”. Finally, they conduct policies to make the economy run to produce certain outcomes. Furthermore, they can accommodate the scale of policy based on the degree of deviation between the actual GDP and the “ability”.

Economists and econometricians have continued to make an effort to approach the best estimation even though they know that they can not obtain a correct answer. They created several indicative concepts of “ability” and took much time to produce tools for measuring them. By virtue of their efforts, almost all estimates stand proof against the above conditions: (1) to possess the previous several results, or (2) to possess the present several results by several means.

Our ultimate objective is to re-examine the past “ability” of the Japanese economy and also to refine and develop a measurement method to estimate a more credible "ability".

1.2 Review of Japan's macroeconomy since 1980

The Japanese economy of the 1980s started after the oil shock of 1979. However, Japan's economy performed beyond the capacity of the time as if there did not exist a negative shock in the early 1980s. Japan's government and the Bank of Japan went through two difficulties: The oil shock of 1979 and the Plaza Accord. However, because the Bank of Japan continued to take a stance of easing monetary policy continuously after corresponding to the shocks, asset prices rose rapidly. Moreover, because of the stable inflation rate, the Bank of Japan failed to tighten the monetary policy and accelerated the rise of asset prices. During this period, the 10 year average of real GDP growth was equal to 4.40%. The 10 year average of inflation was a stable 2.53%. Especially, Japan's economy exceeded the potential conditions prevailing in the late 1980s.

Japan's economy of the 1990s fell rapidly. In December 1989, after setting the highest Nikkei Stock Average ever recorded, the Ministry of Finance of the time notified the total volume control for land to avoid raising real estate prices the next year in March 1990. Therefore, banks suddenly changed their lending attitudes, which had been loose until then, and asset prices fell dramatically. The economy to which Japan has come down recorded a negative growth rate of real GDP and a deflation rate. As if to add insult to injury, in 1997 and 1998, the financial crisis in Southeast Asia negatively affected the Japanese economy, which was under a tight budget. The economy fell into a succession of bank crashes. After the bubble burst, the Bank of Japan presented an easing stance of monetary policy, but it has recognized the economy optimistically. Consequently, 10 year averages of the growth rate and inflation are less than half that of the 1980s: 1.46% and 1.21%.

Japan's economy since 2000 has suffered the aftereffects of the fall of the economy after the bubble collapse. A main feature of the economy of the time was "deflationary concerns". The 10 year average of the real GDP growth rate has been maintained at 0.89%, but the 10 year average of inflation of -0.27% reflects a chronically deflationary economy. During this period, the Bank of Japan took its lessons from the policy mistakes of the 1990s. It implemented a new monetary policy with the commitment that the policy would be taken for a long time. However, the quantitative monetary policy was unable to overcome the chronic deflation of asset prices. Unfortunately, in October 2006, the Nikkei Stock Average recorded its lowest price of the period. Since then, there has been no effective policy to overcome "deflationary concerns". In 2008, there were no opportunities to overcome the deflation because of the global financial crisis, which propagated from the United States. However, the Japan's economy has lately shown signs of an end to the long-run slump.

Chapter 2

Real-Time Estimation of the Equilibrium Real Interest Rate: Evidence from Japan

2.1 Introduction

2.1.1 Motivation

Policy rate decisions made by central banks in real time have a strong impact on an economy. Most central banks in developed countries adopt a short-term nominal interest rate as a policy rate to stabilize economic activity and financial systems: The Uncollateralized Overnight Call Rate in Japan and the Federal Funds Target Rate in the United States are examples of such rates.

Under such a consensus of monetary policy rates, when the central bank sets a target rate for real-time monetary policy, the real equilibrium interest rate (ERR) can be regarded as a benchmark rate among monetary policy rates. Based upon recent macroeconomics, such as the new Keynesian framework, the ERR is defined as the real interest rate in an economy where no distortion of price and wage decisions occurs. Some authors refer to the theoretically based ERR as the natural rate of interest (NRI) [1].

Theoretically, by generating a difference between the policy rate and the

[1] Wicksell (1936) presented a pioneer study of both the ERR and NRI. Blinder (1998) differently names the ERR as the neutral rate.

ERR on purpose, central banks can fine-tune an economy effectively. When the actual real rate is equal to the ERR, the actual output is coincident with the potential output, and prices become stable. If central banks raise their policy rates, then the actual real rate exceeds the ERR and the economy contracts, and vice versa. Therefore, for central banks, perceiving the real-time ERR is important for stabilization of economic activity and prices.

As previous works have presented, it is difficult to measure the true ERR in real time. Nevertheless, many researchers continue to study estimation of the ERR because estimation of the ERR is believed to enable the sensing of economic conditions and to support the appropriate conduct of monetary policy. Specifically, as Orphanide and van Norden (2002) have reported, the monetary authority might confront two uncertainties from available data such that the ERR is discredited in real time when estimating the real-time ERR.

First, one uncertainty arises because of data revision. The data used in estimating the ERR are often revised either once a quarter or once every several years. Therefore, the ERR estimated using real-time data differs from the second ERR using revised data for the same period. Secondly, another uncertainty is attributable to the acquisition of additional data. Even if the data are not revised, additional data become available in subsequent quarters. Therefore, the previously estimated ERR might vary according to the acquisition of new data[2].

The objective of this paper is to point out potential problems that arise in measuring the real-time ERR using both a conventional method and revised data and to obtain some implications for Japan's monetary policy with the specific ERR estimated from a modified model. For these analyses, the author adopts the Laubach and Williams (2003) model (LW model), which is based upon the state-space approach[3]. The LW model has been used in

[2]The latter is generally regarded as the *end-of-sample problem*.

[3]Several approaches have been used to measure the ERR. The first of them is simply a univariate filtering approach, such as a Hodrick-Prescott (HP) filter. Second is a state-space approach that estimates the state variable from a structural macroeconomic model. The common shortcoming of these approaches is the lack of a theoretical background for the ERR. The last one is the dynamic stochastic general equilibrium model with a Bayesian technique. The ERR comes from the Bayesian DSGE model is most consistent with the theoretical ERR. However, few studies have examined the Bayesian DSGE approach. Specifically for Japan's case, Umino (2013) describes the measure of the ERR before the bubble burst. For the UK and EU, see Neiss and Nelson (2003), Smets and Wouter (2003), and Andres et al. (2009) and for the U.S., Edge et al. (2008) and Justiano and Primiceri

many earlier studies. Furthermore, the estimated ERRs for different countries and the model characteristics are reported by them. Consequently, this model can be used to compare the results presented in this paper with those from other works[4].

Moreover, this paper presents specific examination of the control of the uncertainty under which the variation of the ERR results from the data revision[5]. First, to ascertain the degree of uncertainty by revising GDP data, the uncertainties generated by an original LW model are evaluated when the ERR is measured in real time. Second, data used herein are reviewed based upon hints offered by Kamada (2005, 2009) to reduce their associated uncertainty. The original LW model is modified if necessary. Furthermore, uncertainties of the modified LW model are re-evaluated after reflecting Kamada's conceptualization.

This paper is the first study of Japanese data that has solved this important problem confronting each central bank: measuring the ERR in real time. Moreover, the scarcity of Japan's data has supported the implementation of this study. Our analysis includes several novel features that can differentiate this study from the existing literature. First, as a report by Kamada (2009) and other reports of previous studies have described, the real-time estimate obtained from the original model by Laubach and Williams (2003) includes considerable uncertainty because of the inconsistency between vintage data and updated data for the real GDP. Moreover, the original model shows that the components used to construct the ERR amplify the uncertainty.

Second, to reduce this uncertainty attributable to estimates, the original LW model was modified. Furthermore, the usage of data that can be revised was shifted to Japan's superior *Short-Term Economic Survey of Enterprises* in Japan (*TANKAN*). Consequently, the real-time ERR, as estimated by the modified LW model and the usage of *TANKAN* data, can be shown to have less uncertainty than that of the original model.

The real-time ERR obtained from the modified LW model shows three mistakes of the monetary policy management attributable to three judgment errors. First was the time when the economy decided against monetary easing during 1993-1995. Second was the time when the Bank of Japan (BOJ) failed

(2010).

[4]Herein, without eliminating the idea of the original model, a modified approach can be presented that reduces uncertainty, which is an obstacle to policymakers.

[5]Uncertainty that creates variation of the ERR from the acquisition of additional data over time is unavoidable.

to use an opportunity to take a zero interest rate policy (ZIP) in 1997-1999. Finally, the BOJ misled the timing to lift the ZIP in 2000. Specifically, it is easy to imagine that if the BOJ daringly chose a policy with more easing and if there was neither of the first two judgment errors in the early stage of Japan's long-run slump, the recovery of economy would have been brought further forward.

The remainder of the paper is organized as follows. Section 2 presents a description of the original Laubach-Williams model. Section 3 presents an evaluation of the uncertainties from the original LW model in real time and presents some issues for consideration. Section 4 presents revision-free data and modified models, with comparison of uncertainties from the modified model with those of the original model. Section 5 presents some implications for the Bank of Japan's past monetary policy. Section 6 concludes this presentation.

2.1.2 Literature review

This subsection presents a review of some studies of the literature related to the paper contents. With respect to the ERR frequency, these analyses adopt the same frequency as the theoretical ERR from the New Keynesian framework. However, as explained in Maddison (1995) and in Oliner and Sichel (2000), numerous previous studies conducted with monetary policy analysis have shown that ERR is assumed to be constant as the long-term equilibrium rate. One might readily imagine that the real-time ERR reflects the economy of the moment and that it varies over time. Based upon the recent theory of the ERR, Laubach and Williams (2003) and Oda and Muragan (2003) specifically examine a medium-run concept of price stability abstracted from the effects of short-run price and output fluctuation[6].

Second, with respect to revision of GDP data, as from Faust et al. (2005), the feature of the Japan's data revision, i.e., the reason why the preliminary GDP data differ from the true value, is well known to be 'noise.' Furthermore, when one estimates the true value of GDP as the latent variable from the featured GDP data, studies conducted by Mankiw et al. (1984) and Mankiw and Shapiro (1986) revealed that the filtering approach is useful. Therefore, the estimation model for the ERR as a latent variable is applied to the

[6]For the Japanese case, see Oda and Muranaga (2003), Iwamura et al. (2006), and Kamada (2009). For the United States, see Laubach and Williams (2003), Clark and Kozicki (2004) and Trehan and Wu (2007).

Kalman filter. In this sense, using the LW model to measure the ERR can be justified well.

As described in the previous subsection, there must be some uncertainty in measuring whether the output gap or the ERR. Kamada (2009) examined the uncertainty of the Japan's ERR caused by revision of real GDP using a method that differs from ours[7]. Based on the classification of four uncertainties by Orphanides and van Norden (2002), Kamada (2009) reported that the uncertainty of data revision is a fraction of 1% in the estimated ERR. Furthermore, the greatest uncertainty was obtained from the *end-of-sample* problem. These results were equivalent to those presented by Orphanides and van Noden (2002), who used various methods to evaluate uncertainties in the US real-time output gap.

To reduce uncertainty in real-time estimation of the ERR, Kamada (2009) proposed the use of the revision-free data instead of real GDP data. No such proposition has been advanced in previous studies to reduce uncertainty in ERR. The usual GDP data must estimate the latent variables as the potential output or the ERR. However, when ordinary GDP data are not used, the revision-free data are expected to reflect the level of aggregate demand or the output gap.

2.2 ERR estimation model

2.2.1 Original LW model

The equilibrium real interest rate (ERR) is estimated using a model resembling that of Laubach and Williams (2003). The dynamics of the output gap expressed as the IS equation is that of a backward-looking formulation.

$$\begin{aligned} y_t - y_t^* = a_{y,1}(y_{t-1} - y_{t-1}^*) + a_{y,2}(y_{t-2} - y_{t-2}^*) \\ - \frac{a_{r,3}}{2}\left[(r_{t-1} - r_{t-1}^*) + (r_{t-2} - r_{t-2}^*)\right] + \epsilon_{y,t}, \end{aligned} \tag{2.1}$$

where y_t is the real logarithm of GDP; y_t^* is the potential output. Consequently, the output gap $y_t - y_t^*$ is defined as the difference between y_t and y_t^*.

[7]Real GDP data entail several estimates in Japan: the first preliminary (quick) estimate, the second preliminary (quick) estimate, the semi-final estimate, and the final estimate.

Furthermore, r_t is the real uncollateralized call rate, and r_t^* denotes the equilibrium real interest rate. Similarly, the real interest rate gap is expressed as the difference between r_t and r_t^*. Therefore, an IS equation is constructed from the lags of the output gap, the lagged real interest rate gap, and a serially uncorrelated shock.

Second, the AS equation based on the Phillips curve is presented as follows.

$$\pi_t = b_{\pi,1}\pi_{t-1} + \frac{b_{\pi,2}}{3}\sum_{i=2}^{4}\pi_{t-i} + \frac{1 - b_{\pi,1} - b_{\pi,2}}{4}\sum_{i=5}^{8}\pi_{t-i} + b_{y,3}(y_{t-1} - y_{t-1}^*) + b_{\pi^l,4}\pi_t^l + b_{\pi^o,5}\pi_{t-1}^o + \epsilon_{\pi,t}. \tag{2.2}$$

The current inflation π_t is explained by the first through eighth lagged inflation. The sum of all coefficients of the terms of inflation is assumed to be one. Moreover, two restrictions are imposed on the inflation terms in the AS equation. First, the coefficients of the second through fourth lagged variable are assumed to be equal. Similarly, the coefficients of the fifth through eighth lagged variable are assumed to be equal. Gordon (1998) and Laubach and Williams (2003) are followed to set such restrictions. Two variables are set: core import price inflation π^l (excluding petroleum, computers and semiconductors) and lagged crude imported oil price inflation π^o. Relative oil price shocks are measured using them. Finally, in addition, the AS equation consists of the lagged output gap and a serially uncorrelated error.

From Equations (1) and (2), characteristics of the ERR in the paper are apparent. The definition of the ERR is the real interest rate that keeps inflation stable and that which neither accelerates nor decelerates economic activity. The definition of the estimated ERR in this paper must cover that of the theoretical ERR. The definition of the theoretical one is the real interest rate in the economy having no distortion of the decision of prices and wages. Therefore, tightening the assumption that the inflation rates of prices and wages are stable, the definition of the theoretical ERR overlaps with that of the estimated ERR. It is particularly interesting that the restriction "the sum of lagged coefficients to one" strongly affects the definition of the measured ERR[8].

As described by optimal growth theory and New Keynesian theory, ERR is usually correlated with the growth rate trend. It also depends upon the

[8]See Appendix A for more information.

household's rate of time preference. In this study, therefore, the form of the ERR is defined as shown below.

$$r_t^* \equiv c \cdot g_t + z_t. \tag{2.3}$$

where g_t signifies the annualized trend growth rate of real output, and z_t is the factor that influences household consumption demand. Therefore, z_t is regarded as the demand component, for which the process shown below follows if high persistency holds.

$$z_t = z_{t-1} + \epsilon_{z,t} \tag{2.4}$$

Consequently, z_t is set as a random walk process. As Laubach and Williams (2003) described, the reason for the random walk process specification is that because the estimated ERR derives from the AR process, it exhibits large short-duration swings. If this persists, then the ERR's definition of frequency fails.

Finally, data-generating processes of the potential output and the trend growth rate are given as presented below.

$$y_t^* = y_{t-1}^* + g_t + \epsilon_{y^*,t}, \tag{2.5}$$

and

$$g_t = g_{t-1} + \epsilon_{g,t}. \tag{2.6}$$

where g_t is defined as the annualized trend growth rate of the potential output. Furthermore, ϵ_{y^*t} and $\epsilon_{g,t}$ are assumed as serially uncorrelated and contemporaneously uncorrelated error. Our formulation of the growth rate trend is given by Kuttner (1994) and is adjusted by many previous studies. In this form, the trend growth rate is assumed to vary at small variance every quarter because it is difficult to assume that the trend growth is constant.

The original LW model includes some unobservable variables. This model is designated as an unobserved component (UC) model. A Kalman filter is useful to estimate the UC model and to generate unobserved data. This paper presents the state-space representation of original LW model and applies Kalman filtering to this representation.

2.2.2 Estimation results

The estimate of ERR for Japan and the data used are shown as quarterly during 1980Q3 to 2010Q2 in Japan. The logarithmic real GDP (seasonal adjusted) is used as the measure of output and consumer price index (excluding fresh food, seasonally adjusted) as the measure of prices. The expected inflation is calculated from the forecast of the univariate AR(3) model. The nominal interest rate is the quarterly average of the overnight uncollateralized call rate, expressed in units of percent per year. The price index of non-oil imports is not available in Japan. The imported price index is applied to π^l_t and π^o_{t-1}.

As Laubach and Williams (2003) described, the maximum likelihood estimates of the standard deviations of the innovations to the trend growth rate g_t and the demand components z_t, σ_g and σ_z are likely to be biased toward zero. This phenomenon is the '*pile-up*' problem that Stock (1994) and Stock and Watson (1998) pointed out. To address this problem, this study uses the medium unbiased estimator suggested by Stock and Watson (1998). Consistent estimates of the ratios, $\lambda_g \equiv \sigma_g/\sigma_{y^*}$ and $\lambda_z \equiv a_{r,3}(\sigma_z/\sigma_y)$, are obtained in the first estimation. In the final estimation, these restrictions are imposed to obtain the maximum likelihood estimation.

Table 1 presents estimation results of the original model parameters for different model specifications. In all cases, the coefficients relating the output gap to the real rate gap, $a_{r,3}$, are negative and statistically significant. The second and third columns report results in the models in which the original LW model is modified. Especially in the third column, coefficient $a_{r,3}$ is extremely small compared to those reported by Kamada (2009) in Japan and Clark and Kozicki (2005) in the US, which were obtained assuming the same model.

The sample period in this study includes the financial crisis event. Some authors have described that the economic structure changed after the financial crisis. Therefore, it was tested whether this study must consider the change of the structural break with my estimation. Dividing the sample period, the estimated parameters over the sub-sample were compared with the estimated ones over the full sample. Appendix B shows more information. Fundamentally, results show that the analysis need not consider the structural break with the estimation.

Moreover, when the original and a different specification model are estimated in a sub-sample from 1999Q1, even then Japan's nominal interest rate remains at around zero, which confirms that each estimation result of model parameters is robust.

2.3 Evaluation of uncertainty

2.3.1 Definitions of uncertainty

The uncertainty caused by data revision and accumulation can affect the action of a central bank. In this context of the output gap, Orphanides and van Norden (2005) define output gap estimates of four kinds: *real time*, *quasi-real*, *quasi-final*, and *final* output gaps. In this case of the ERR, the ERR is estimated using only vintage data available for each point in time. Consequently, the *real-time* ERR is obtained. Next, when a counterfactual assumption is made that the ERR at period t is calculated using the full sample data series 1 through $T(> t)$, the *quasi-real* ERR is estimated. For the *quasi-final* ERR, another counterfactual assumption is made that the ERR at period t is calculated using the estimated model parameters at period T and the final data series. Then, the *quasi-final* ERR is calculated. The *final* ERR is a series estimated from all data in period t. It is used in usual analysis. Moreover, for UC models, the quasi-final ERR is a filtered estimate, whereas the final ERR is a smoothed estimate.

As discussed in some previous reports of studies, three uncertainties are defined through each difference in the four ERR estimates above. First, the difference between the real-time and quasi-real ERR estimates is attributable to the effect of data revision. This study refers to the effect of the first uncertainty as *Error 1*. Second, the difference between the quasi-real and quasi-final ERR estimates is attributable to the effect of model parameter revision. This study specifically examines the effect of the second uncertainty as *Error 2*. Finally, the difference between the *quasi-final* and *final* ERR estimates is generally attributable to the effect of the *sample-end problem*. This study refers to the effect of the third uncertainty as *Error 3*.

2.3.2 Evaluation

Complete real-time GDP data for Japan are unavailable. A dataset such as the US real-time dataset by the Federal Reserve Bank of Philadelphia is unfortunately not published as historical data. Therefore, the first published real GDP data were used - the first quick estimate - from the *Nikkei News Paper* (*Nihon Keizai Shinbun*). Table 2 below presents those results:

1) *Error 1* in most estimated state variables is greater than *Error 2* or *Error 3*

2) *Error 1* in the potential output, which is apparently influenced directly by the revision of GDP, is noticeable

3) Two components of which the ERR consists, 'g' and 'z', are apparently sources of high uncertainty in the ERR

4) Because of the data-generating processes of 'g' and 'z', the uncertainty of the ERR can be amplified to a greater degree than necessary

Results 1) and 2) show that the real-time latent variables are affected by the revision of real GDP. From the first column of Table 1, the uncertainty of ERR (*Error 1*) is 0.58%. Considering the situation of long-run low interest rate in the estimate period, this value is larger. Similarly, *Error 1* in the potential output is larger than the other errors. However, *Error 1* of the ERR is larger than that of the potential output. Moreover, the two components that must be estimated first to calculate the ERR, 'g' and 'z', have respective uncertainties that are greater than 1%.

The outcome that the uncertainty of the potential output is higher than that of the ERR has a close relation with the outcome that the uncertainties of both g and z are extremely high. The relation is involved in the mechanism that the uncertainty accumulates or propagates from measurement of the potential output to the measurement of the ERR. First, to measure ERR, one must have the estimate of the potential output. Next, one can measure g in estimating the potential output. Finally, in measuring the ERR, under the estimated g, one can obtain z, which involves the remaining information to estimate the ERR. Then, the accumulation of uncertainty starts from both potential output and g, which are estimated contemporaneously. Furthermore, because of the random walk process in g, the uncertainty persists and fluctuates. In the step to measure the ERR, the uncertainty of g is transmitted to z. The uncertainty in z is also persistent and fluctuating.

Especially, from the figure, one can infer that component z strongly influences the uncertainty of the ERR. Figure 1 displays real-time ERR under conditions where the BOJ estimates the original LW model every quarter and refers to the ERR of the end-of-sample as the real-time estimate. Furthermore, for the GDP data, using a quick estimate in the terminal period t and replacing the value of the previous t with a revised estimate in the next period $t + 1$, the full sample data are updated and accumulated.

As the figure shows, the difference between the original ERR and g shows z. From the figure, one can understand that the revision of GDP affects the ERR strongly and that the source of uncertainty is the component z. Two definite gaps are apparent during 1993−1998 and 2001−2005. During 1993−1998, a strong influence of z is found because the quick estimate was underestimated below the revised estimate. In contrast, during 2001−2005, a strong influence of z is applicable because the quick estimate was overestimated above the revised estimate.

2.4 Modifications and re-evaluation

2.4.1 Modifications

According to the results described above, it is necessary to reduce the uncertainty of ERR in a real-time estimate, as summarized in the following two points: (1) rethinking data that present a possibility of revision and (2) reviewing the data-generation processes of 'g' and 'z'.

The best means to reduce uncertainty is to avoid using data that might be revised, but this mode of measuring the ERR is not feasible. Data that might be revised, such as real GDP, are important to estimate latent economic indicators. Therefore, if real GDP data are not used, then data must be prepared that are not revised and which have information related to current economic activity such as real GDP. Kamada (2005, 2009) reported such data in the context that it remedies the real-time output gap. Such supplementary data are taken from the *Short-term Economic Survey of Enterprise* in Japan, *TANKAN*. The *TANKAN* aims at contributing to the appropriate implementation of monetary policy by capturing business trends of enterprises accurately.

Japan's diffusion index (DI) in the *TANKAN* data is suitable as a proxy of the output gap in that the question format is based on fulfillment. Other countries have no such data, although many countries report DI related to production. For example, one can consider that the Purchasing Managers' Index (PMI) published by the Institute for Supply Management (ISM) might be available as a proxy of the output gap and the variable close to the Japan's DI. However, the PMI is inappropriate as a proxy for the following reasons: 1) there exists no question item to construct a Cobb-Douglas style production function, especially not a question item related to productive capital; 2) fundamentally, the question format asks the degree of improvement from the previous period, not the question format of "fulfillment". Consequently, the uncertainty of Japan is only reduced.

Kamada (2005, 2009) reports the use of a "Business Conditions" DI of 10 items in the *TANKAN*. This DI reflects a judgment of general business conditions of the responding enterprise in light of the company's profits. However, this DI is not applied for this study. A critical reason that the paper does not adopt the "Business Conditions" DI is that, by using it, I can not maintain the justification over the theory of the ERR (e.g., New Keynesian framework). It is difficult to understand the "Business Conditions" DI that expresses the condition to various aspects of production.

Instead, a *weighted* DI is proposed. The reason that the *weighted* DI is used for this study is the following. If the expression of output in an actual economy is approximated using a Cobb-Douglas production function that is usually used in the theoretical model, then the (log-linearized) output gap is given as

$$\ln Y_t - \ln Y_t^* = \alpha(\ln L_t - \ln L_t^*) + (1-\alpha)(\ln K_t - \ln K_t^*)$$

where α stands for a labor income share. The Cobb-Douglas type of the output gap ($\ln Y_t - \ln Y_t^*$) is given as the weighted average of the deviations between actual and potential quantity (with a superscript '*') in terms of labor input ($\ln L$) and capital input ($\ln K$)[9]. Based upon the setting, the weighted DI in this paper shares the same idea with the Cobb-Douglas type of the output gap. The weighted DI actually comprises two DIs.

$$\begin{aligned}&\text{the } \textit{weighted} \text{ DI}\\ &= \alpha \times \text{“Employment Condition” DI} + (1-\alpha) \times \text{“Production Capacity” DI},\end{aligned}$$

where α is a labor income share[10]. The "Production Capacity" DI is a judgment of excessive, adequate, or inadequate production capacity or business

[9]It frequently arises in the minutes of monetary policy meetings because this DI is superior to the "Business Condition" DI in that a DI that reflects the output gap is sought here.

[10]It is assumed to be 0.64.

equipment of the responding enterprise[11]. The "Employment Conditions" DI is a judgment of excessive, adequate, or inadequate number of employees at the corresponding enterprise[12]. The results of the survey items "Employment Conditions" and "Production Capacity" in the *TANKAN* present the difference between the current position over the production factors and the appropriate position considered by the respondents. Therefore, because the components of the *weighted* DI are conceptually consistent with the components of the theoretical output gap, the *weighted* DI can be regarded as the output gap.

When the revision-free data are used and the processes of both 'g' and 'z' are reconsidered, it is necessary to modify the original LW model. Herein, the following two versions of the modified LW model are proposed:

Version 1 is to use both the weighted DI and ordinary GDP data, and to reconsider both 'g' and 'z' processes.

Version 2 is to use the weighted DI only and to reconsider both the 'g' and 'z' processes.

2.4.2 Re-evaluation

First, the author examines the relation between the *TANKAN* and '*noise*' before applying the *TANKAN* to the ERR estimation model. No real-time dataset has been reported in Japan. Therefore, the author gathered both the first preliminary and second preliminary GDP published in 2006Q1-2011Q2 (benchmark year 2000). The GDP data published first at some point takes around three years to reach a stable number. Therefore, if the GDP published three years later is the true one, then the difference between each revised GDP and the three-year-later GDP is regarded as noise. Figure 2 presents the relation between noise and *TANKAN*. The figure displays a positive correlation, thereby ensuring that *TANKAN* is helpful to estimate the true output gap.

[11]This DI excludes shortages caused by temporary conditions such as a factory closure for regular repairs.

[12]The "Business Condition" DI and the "Employment Condition" DI are available from 1980Q1. However, the "Production Capacity" DI is available from 1990Q1. Consequently, the "Business Condition" DI 1980Q3 through 1989Q4 is used. Then the *weighted* DI is adopted.

Based upon the proposition of the two types of baseline LW model in the previous section, for **Version 1**, the two measurement equations of the baseline model are retained with no change and modify the transition ones only. This model uses both data that have a possibility of revision (ordinary real GDP) and non-revised data (the *weighted* DI). As discussed in the preceding section, because the published *weighted* DI already includes a gap form, it plays a role as a guide of the dynamics of the output gap, as

Based upon the proposition of the two types of original LW model in the previous subsection, for **Version 1**, the two measurement equations of the original model are retained with no change and modify the transition ones only. This model uses both data that have a possibility of revision (ordinary real GDP) and non-revised data (*weighted* DI). As discussed in the preceding section, because the published *weighted* DI already includes a gap form, it guides the dynamics of the output gap, as presented below.

$$r_t^* = 4c(y_t^* - y_{t-1}^*), \tag{2.7}$$

and

$$(y_t - y_t^*) = f \cdot x_t + \epsilon_{y^*,t}, \tag{2.8}$$

where variable x_t corresponds to the *weighted* DI in the data series; $\epsilon_{y^*,t}$ is a serially uncorrelated error. This model is designated as the **Version 1** model, which can estimate the potential output simultaneously.

However, when the *weighted* DI is fully reviewed as an alternative measure of the output gap, the *weighted* DI can be substituted for the output gap $y - y^*$ in Eq. (1). Then the original LW model transforms into a very simple model. The Phillips curve, Eq. (2), drops from the original LW model. The ERR is simply a random walk process, as in specifications explained by Clark and Kozicki (2005).

$$x_t = a_{x,1}x_{t-1} + a_{x,2}x_{t-2} + \frac{a_{r,3}}{2}\left[(r_{t-1} - r_{t-1}^*) + (r_{t-2} - r_{t-2}^*)\right], \tag{2.9}$$

and

$$r_t^* = r_{t-1}^* + \epsilon_{r^*,t}, \tag{2.10}$$

Therein, the variable x_t which corresponds to the *weighted* DI in the data series is the output gap and $\epsilon_{r^*,t}$ is a serially uncorrelated error. This model is designated as the *Version 2* model. Unlike the *Version 1* model, the *Version 2* model can not estimate the potential output simultaneously.

Therein, the variable x_t, which corresponds to the *weighted* DI in the data series, is the output gap; $\epsilon_{x,t}$ and $\epsilon_{r^*,t}$ are serially uncorrelated error values. This pilot model is designated as the **Version 2** model. Unlike the **Version 1** model, the **Version 2** model can not estimate the potential output simultaneously.

Table 3 shows that the greatest uncertainty in the ERR and output gap becomes less than those in the original LW model. For the **Version 1** model, the ERR's uncertainty caused by the data revision (*Error 1*) is decreased by 85% relative to that obtained using the original model. In addition, uncertainty in the output gap drops to a much lower value. The *sample-end problem* in both ERR and output gap (*Error 3*) is mitigated. Based on results obtained for the **Version 2** model, of course, because real GDP is not used, the uncertainty by the data revision does not rise. Instead, the *Error 3* increases by 2.6%.

The ERR comes from the modified model that strongly involves the influence of data revision. Given the figure of the data series of both the modified ERR and the original one, they must mutually differ for two reasons. First, in measuring the ERR obtained from the original LW model, the stage to measure the potential output is highly sensitive to the data revision. Furthermore, the influence spreads to the stage to estimate the demand shock component 'z', and to 'z' itself, amplifying the influence of the data revision. Although measuring the ERR from the modified LW model is expected to be influenced by the data revision, which is the same degree as the case of the original ERR, because the *weighted* DI gives the direction to measure the potential output, the influence of the data revision on the estimated ERR becomes small. Second, put simply, if the degree of the data revision is large, then the two ERRs differ greatly.

2.5 Implications for BOJ monetary policy

This section presents implications for the BOJ's monetary policy through the estimated historical ERR derived from the model modified from the original LW model. Similarly to Figure 1, Figure 3 displays real-time ERR estimated from the modified LW model corresponding to the **Version 1** model (solid line). The real-time ERR is estimated from the original LW model (dashed line).

A characteristic of the figure shown above is that the estimated ERR from the modified model differs from the ERR from the original model during 1993-1997 and 2001-2005. This difference is caused by the difference between the first preliminary estimate of GDP and the second preliminary one. The gap separating the modified ERR and the original one during 1993-1997 results from the more-underestimated first preliminary GDP than from the second preliminary estimate. Furthermore, the demand shock component z which absorbs the effect of the gap separating the first and second preliminary GDP amplifies the uncertainty of ERR in real time. The gap of 2001-2005 similarly stems from the overestimated first preliminary GDP relative to the second preliminary GDP.

With acknowledgment of the two gaps in those two periods, the validity of the judgment of the past monetary policy management will be reviewed because the modified ERR has higher liability than before.

As might be expected for a period such as the lost two decades, the modified ERR is shown below. Specifically, the sample average of the modified ERR is 0.54%. Furthermore, examination of the monetary policy implications from the modified ERR revealed that the BOJ has made three mistakes in its implementation of policy.

1993-1995

Judgment error (1): First chance to introduce a zero interest rate policy (ZIP)

The BOJ overlooked some fortuitous timing when it should have eased its monetary policy. During 1993-1995, the figure displays the stable modified ERR at a low level attributable to the influence of economic shrinkage deriving from Japan's bursting bubble. However, in comparing the modified ERR with the call rate, the stance for monetary policy shows tightening. In fact, the BOJ should have lowered the call rate at that time. Furthermore, as implied by the rise of the modified ERR that is apparent from 1996, Japan's economy grew despite a small improvement. Therefore, the stance for monetary policy exhibits easing temporarily until mid-1997.

The BOJ took the unexpected tightening stance for monetary policy during 1993-1995 because it emphasized that prices were stable. As evidenced by some observable data, during the middle of 1994-1997, a marked recovery was confirmed from the results of the modified ERR in real time. Because this resurgent trend likely turned out to back up the BOJ's monetary policy, the implicit tightening stance was maintained in the early 1990s. However, as Jinushi et al. (2000) reported, in considering the long-run slump, the BOJ optimistically assessed the economic and financial situation and failed to acknowledge the potential severity of debt deflation. Therefore, it can be in interpreted as a judgment error by the BOJ during that time. A further loosening in 1993 or 1994 might have achieved change in the speed of recovery, which is a possible explanation for a judgment error in 1993-1995 explained above.

1997-1999

Judgment error (2): A delay in adopting ZIP

Japan's economy in 1997 underwent the Asian financial crisis and Japanese bank crisis. The modified ERR in 1997Q4 reached -0.33% below zero for the first time because the bubble burst and fell to a record-low -1.69% in 1998Q1. Furthermore, then, the estimated ERR remained negative until 1999Q1. This result is reasonable and insightful[13]. The growth rate of GDP exhibited a record-low -2.54% in 1998Q1. The actual economy slowed drastically to average -2.12% during 1998. Both the actual and potential economy were in a deep slump, underscoring the severity of Japan's fundamental difficulties.

Despite a definite economic slowdown, the BOJ had set the ZIP in 1999. This delay in policy decision is explainable: the BOJ has no severity in recognition of that contemporary economic situation. The weakness in the judgment of economic conditions within the BOJ is evident from a newspaper interview with the Director-General of the Research and Statistics Department of the BOJ of that time[14]. From that interview, the director presents his view that only a small probability exists of Japan's economy falling into a deflationary spiral. However, considering that the current ERR reaches a record-low -1.69% and that nominal interest rates are substantially positive, the downward money demand of firms might have occurred; then prices might have declined by reducing production (supply curve shifts down), and the economic recession might have accelerated. Therefore, sufficient prob-

[13]The original ERR even reached the zero lower zone in 1998Q2 and 1998Q3.

[14]See Nikkei News Paper, page 5, 14 May, Morning edition, 1998. The article ID: NIRKDB19980514NKM0045.

ability of a deflationary spiral existed at that time. As explained above, because each estimate of the ERRs in the figure displays the values that are available at the time when the BOJ chooses monetary policy, the BOJ definitely made a mistake in timing to take the ZIP again. Indeed, the BOJ adopted the policy at a time when one year had fully passed because the modified ERR fell below zero. Ideally, the policy might have been embraced after the banking crisis. This is a possible explanation for a judgment error in 1997-1999 described above (Fig. 3).

2000

Judgment error (3): Losing recognition of current conditions when lifting the policy

With respect to lifting the ZIP, the figure also reveals the weakness of the BOJ's recognition of the economic situation in 2000. The GDP growth rate rose to 2.40% and 2.16% in 2000Q1 and Q2. Under the recognition of recovery, the monetary policy meeting decided to lift the ZIP in August 2000 because the policy was adopted in February 1999. From the minutes of the monetary policy meeting of that time, the board member shared the current economic situation "the economy had reached the stage where deflationary concern had been dispelled". However, the recognition remained doubtful. The modified ERR was 1.31% in 2000Q2, when the GDP growth rate was much higher than the ERR: 2.16%. The real economy temporarily exceeded the potential economy without just cause. Therefore, the release of the ZIP should have been rejected as premature.

From the minutes of the monetary policy meeting of August 2000, it can be interpreted that a downward risk existed for the actual economy. Ex-Member of the monetary policy Kazuo Ueda persuaded other members and the BOJ's executives, who had tried to pass the Chairma's 'lifting' policy proposal. He said that the remaining possibility that Japan's current economy still faced deflationary concerns and the output gap[15]. Moreover, he remarked that bearing in mind that the nominal interest rate had been kept close to zero to that time, they should not decide to lift the policy based on that positive information, which was such weak information that the BOJ

[15]See Ueda's statement under debate on economic and financial developments in August 11, 2000.

could not fine-tune the policy rate[16]. The minutes from 2000 reveal that most members did not consider rechecking the economy, although the economic recovery did not involve the upward potential growth rate. This is a possible explanation for the judgment error in 2000 described above (Fig. 3).

2001-2005

The timing of introduction of quantitative easing (QE) policy and the continuation of the policy thereafter are appropriate, unlike other judgment errors. Immediately before adopting the QE policy in 2000Q4, the modified ERR recorded 1.66% and declined continuously thereafter. In 2001Q3, the estimated ERR reached the zero lower zone again. In fact, the BOJ adopted the QE policy as a new monetary policy in 2001Q1. By changing the main operating target for money market operations to the outstanding balance of the current account at the BOJ, it is not proper to analyze monetary policy through a comparison between the ERR and the call rate. However, the consistent policy that gives the easing stance has no effect on the real economy except when the ERR is below zero (2001Q3-2002Q2).

2006-

The stance of continued easing until the financial crisis is appropriate. After releasing the QE policy, the modified ERR did not fall below zero before the financial crisis. It hovered around 1%. Interpreting the monetary policy from the modified ERR, from the nearly 1% ERR and the deflationary expectation that has remained, it is inferred that the equilibrium nominal interest rate was close to zero. Such a low-equilibrium nominal interest rate is consistent with the actual nominal rate. Consequently, the stance for continued monetary policy intervention can be supported.

2.6 Conclusion

The notion of measuring the ideal level of something, such as ERR, is akin to the notion of calculating a class curve of a placement test. The class curve of the routine test that is taken at the time of the academic ability test

[16]See Ueda's statement under debate on monetary policy for the immediate future in August 11, 2000.

corresponds to the momentum at that time (the policy rate). The deviation value depends both on the current ability of a student and the student's condition at the time the placement test is taken. It has good quality and remains stable. When a student who has some level of ability receives a low deviation value in the placement test, the reason for the result might derive from some exogenous factor, such as illness. This phenomenon corresponds to an economic shock in terms of economics. Finally, the teacher grades the placement test and considers the periodic exam. Then the teacher instructs the students appropriately.

Similar to that concept of a class curve, the ERR is extremely important for an agent in an economy. Especially for a central bank, which has an obligation to navigate the economy, measuring ERR that is always up-to-date and accurate is an important task. However, the problem of real-time estimation that Orphanides and van Norden (2002) pointed out also arises in estimating the ERR when the central bank attempts to capture the ERR dynamics in real time using all available data. Results of this study showed that the real-time estimation of the ERR using the method of Laubach and Williams (2003) includes several types of uncertainty that arise through processes of data revision and accumulation. The central bank faces the risk of making a poor decision about monetary policy using the real-time ERR. Especially, the effect of the data revision is not negligible in the context of a zero bound interest rate. The model specification amplifies such effects. Therefore, to reduce the uncertainties of the real-time ERR estimate, when the revision-free data, specifically the weighted DI for *TANKAN*, were used as an indicator of the output gap and the LW model was modified appropriately, most uncertainties in the modified LW models became lower than those of the original LW model.

Regarding past monetary policy, the BOJ made three mistakes: 1) it failed to ease the monetary policy aggressively immediately after the bubble burst; 2) it waited to implement ZIP after the Asian financial crisis and the Japanese banking crisis; 3) it rushed the decision to lift ZIP. Although not all causes of Japan's long-run stagnation are related to the BOJ's monetary policy, considering that the BOJ is an agent intended to safeguard the economy, it must make correct decisions using accurate information.

Possible extensions can be made to this avenue of research. First, the influence of financial factors on the ERR has not been examined. It is necessary to construct a new weighted or composite DI that captures the business fluctuation originating in the financial system using financial DI published in the *TANKAN*. Second, the estimated ERR described in this paper is not consistent with the theoretical concept. Using a Bayesian DSGE model, it is necessary to measure the ERR and to present the problem in real-time estimation. Therefore, comparison of results obtained from the Bayesian DSGE model with this paper can contribute to efforts to measure ERR more accurately.

Table 2.1: Parameter Estimates

	original LW model		**Version 1**		**Version 2**	
Parameters	Estimates	t-value	Estimates	t-value	Estimates	t-value
$a_{y,1}$	0.660	2.508	1.025	26.746	0.986	16.484
$a_{y,2}$	0.285	1.083	0.007	6.571	0.005	1.357
$a_{r,3}$	-0.114	-2.253	-0.006	-8.665	-0.015	-4.214
$b_{\pi,1}$	0.688	5.516	1.305	0.571		
$b_{\pi 2}$	0.109	0.595	0.198	0.146		
$b_{y,3}$	1.026	2.078	0.047	4.590		
$b_{\pi^m,4}$	0.008	1.006	0.039	0.857		
$b_{\pi^m,5}$	0.006	0.883	-0.017	-0.484		
c	0.948	0.795	0.681	3.593		
f			0.060	1.786		
σ_y	0.948	2.472	0.362	2.880	0.413	9.063
σ_π	0.619	4.990	0.491	6.526		
σ_{y^*}	0.846	9.940	0.233	4.461		
σ_g	0.177					
σ_z	0.886					
σ_{r^*}					0.552	
MUE	λ_g =0.210				λ_{r^*} =0.020	
	λ_z=0.224					

Note: $\lambda_g = \sigma_g/\sigma_{y*}, \lambda_z = a_{r,3}(\sigma_z/\sigma_y), \lambda_{r^*} = a_{r,3}(\sigma_{r^*}/\sigma_y)$.
All estimates are for 1980Q3–2010Q2.

Table 2.2: Evaluation of the uncertainty on the baseline LW model.

	Error 1	*Error 2*	*Error 3*
r^*	0.584	0.022	0.739
g	1.363	0.041	0.515
z	1.377	0.016	0.603
$y - y^*$	0.299	0.015	0.268

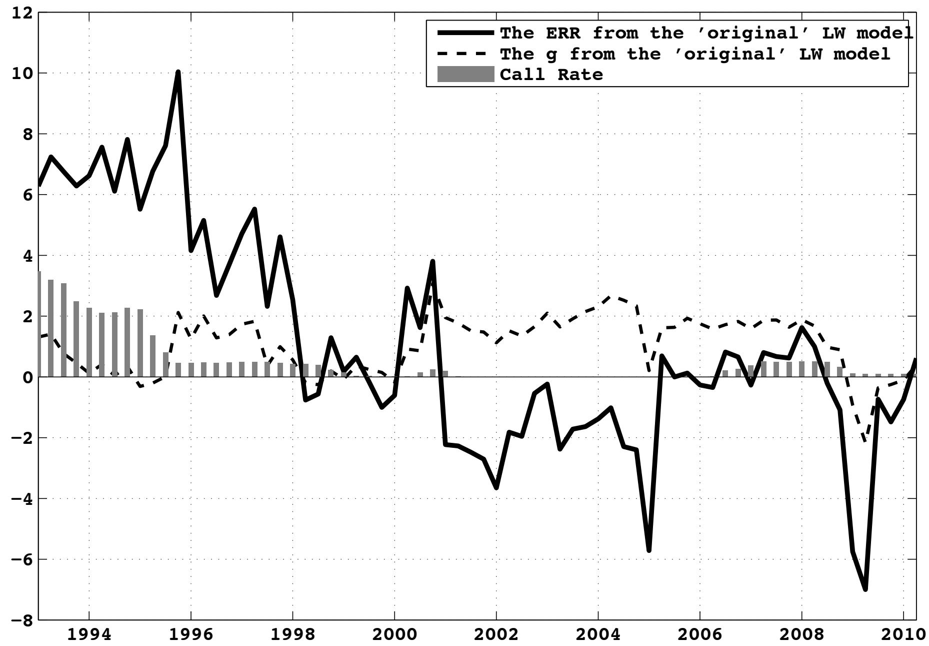
Note: All numbers are root square means of the revision series shown. All statistics are for 1993Q1–2010Q2.

Table 2.3: Evaluation of uncertainty of the modified models.

		Error 1	*Error 2*	*Error 3*
Version 1	r^*	0.083	0.208	0.258
	$y - y^*$	0.0002	0.002	0.258
Version 2	r^*		0.069	2.602

Note: All numbers are root square means of the revision series shown. All statistics are for 1993Q1–2010Q2.

Figure 2.1: Real-time ERR estimated from the "original" Laubach-Williams model



Note: The ERR is shown as the solid line; the trend growth rate is shown as the dashed line. The call rate is shown as the bar graph. The sample period is 1993Q1-2010Q2.

Figure 2.2: Preliminary data revision and the *weighted* DI

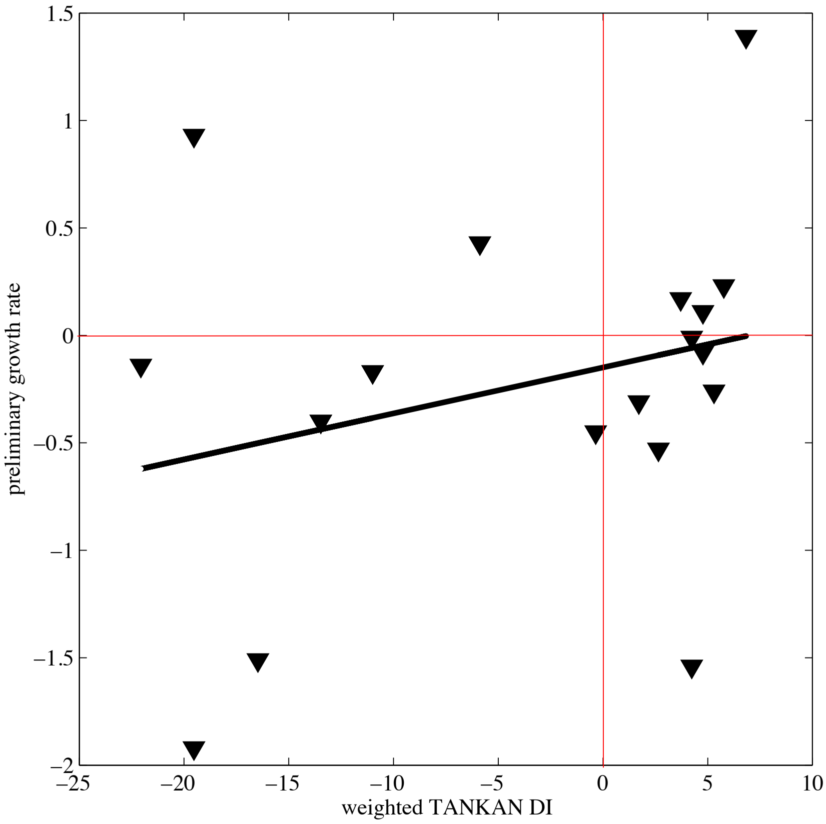
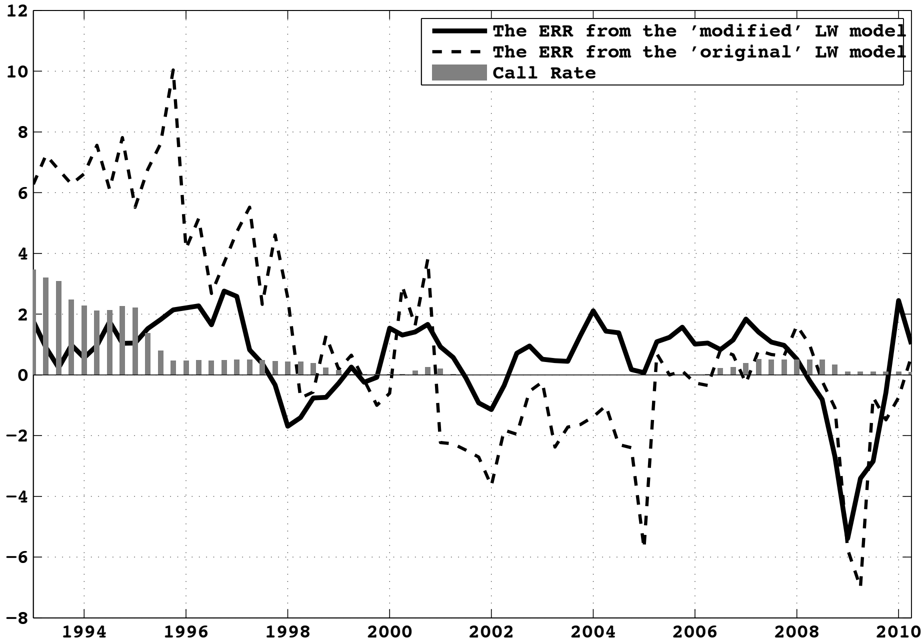


Figure 2.3: Real-time ERR estimated from the "modified" Laubach-Williams model



Note: The "modified" ERR obtained from the **Version 1** model is a solid line; the "original" ERR is a dashed line. The call rate is shown as the bar graph. The sample period is 1993Q12010Q2.

2.7 Appendix A Restriction: "sum of the coefficients to one"

With respect to the restriction of the coefficient on the lagged inflation terms, if there is neither the restriction nor import inflation (shock), then Equation (2) can be rewritten as

$$\pi_t = b_{\pi,1}\pi_{t-1} + b_{\pi,2}\pi_{t-2\sim4} + \delta\pi_{t-5\sim8} + b_{\pi,3}(y_{t-1} - y^*_{t-1}), \tag{2.11}$$

where $\pi_{t-2\sim4} \equiv \frac{1}{3}\sum_{i=2}^{4}\pi_{t-i}$ and $\pi_{t-5\sim8} \equiv \frac{1}{4}\sum_{i=5}^{8}\pi_{t-i}$. In this case, the first restriction that the coefficients on the second through fourth lags of inflation are assumed to be equal to each other as are the coefficients on the last four lags have been maintained. If the following equation holds,

$$\pi_t = \pi_{t-1} = \pi_{t-2\sim4} = \pi_{t-5\sim8} = \mu, \tag{2.12}$$

then the AS curve can be rewritten as

$$\mu = b_{\pi,1}\mu + b_{\pi,2}\mu + \delta\mu + b_{\pi,3}(y_{t-1} - y^*_{t-1}), \tag{2.13}$$

and

$$(y_{t-1} - y^*_{t-1}) = \{1 - (b_{\pi,1} + b_{\pi,2} + \delta)\}\frac{\mu}{b_{\pi,3}}. \tag{2.14}$$

When the restriction $b_{\pi,1} + b_{\pi,2} + \delta = 1$ is introduced, then the expression above can be finally rewritten as

$$(y_{t-1} - y^*_{t-1}) = 0, \tag{2.15}$$

or

$$y_{t-1} = y^*_{t-1}. \tag{2.16}$$

The restriction "$b_{\pi,1} + b_{\pi,2} + \delta = 1$" can be reinterpreted. Holding the restriction assures that, if in an economy

strict assumption The inflation rate is stable over the past two years

mild assumption The current inflation is equal to both previous inflations, $\pi_{t-2\sim 4} = \frac{1}{3}\sum_{i=2}^{4}\pi_{t-i}$ and $\pi_{t-5\sim 8} = \frac{1}{4}\sum_{i=5}^{8}\pi_{t-i}$, then the actual output reaches the potential output.

Consequently, the equilibrium real interest rate can be measured because of that restriction.

2.8 Appendix B Robustness check

With respect to structural breakdown during the financial crisis, the model parameters were re-estimated with the following sample period of three kinds.

Table 2.4: Parameter estimations for robustness check

	1980q3-2007q4	1980q3-2008q4	1980q3-2010q2
$a_{y,1}$	0.660 (2.225)	0.660 (2.361)	0.660 (2.508)
$a_{y,2}$	0.285 (0.999)	0.285 (1.028)	0.285 (1.083)
$a_{r,3}$	-0.114 (1.996)	-0.114 (2.180)	-0.114 (-2.253)
$b_{\pi,1}$	0.688 (4.586)	0.688 (4.848)	0.688 (5.516)
$b_{\pi,2}$	0.109 (0.504)	0.109 (0.515)	0.109 (0.595)
$b_{y,3}$	1.026 (1.800)	1.026 (1.926)	1.026 (2.078)
$b_{\pi^m,4}$	0.008 (0.957)	0.008 (0.966)	0.008 (1.006)
$b_{\pi^m,5}$	0.006 (0.763)	0.006 (0.769)	0.006 (0.883)
c	0.948 (0.654)	0.948 (0.660)	0.948 (0.795)
σ_y	0.458 (2.186)	0.458 (2.275)	0.458 (2.472)
σ_π	0.619 (4.507)	0.619 (4.664)	0.619 (4.990)
σ_{y^*}	0.846 (6.231)	0.846 (6.886)	0.846 (9.940)

Note: Parentheses present t-value.

In the table shown above, comparing the full-sample estimated parameters with the estimated parameters for two other sample periods, no difference arises from rounding off to three decimal places. Rather, the differences derived from rounding to the eighth decimal places are small. Therefore, consideration of a structural break by that financial crisis is unnecessary.

Chapter 3

Structural Estimation of the Equilibrium Real Interest Rate: A Bayesian DSGE Approach

Monetary policy analysis often takes account of the real interest rate gap, defined as a deviation of the actual real interest rate from the equilibrium real interest rate (ERR) because the real interest rate gap is regarded as an important indicator of overall macroeconomic conditions and because it plays an important role in the determination of monetary policy. A crucial problem is that the ERR is not observable, forcing researchers to rely on uncertain estimates. A main objective in this paper is to measure Japan's real interest rate gap and also the ERR.

As described in this paper, a first sub-objective is to reevaluate monetary policy in the late 1980s using the interest rate gap from a dynamic stochastic general equilibrium (DSGE) model with structural estimation, especially related to the natural rate of interest that is definable as the ERR consistent with price flexibility, following Woodford (2003) and Neiss and Nelson (2003). Therefore, we can explore the possibility of application to monetary policy. Especially, the conclusion reported by Jinushi, Kuroki, and Miyao (2000) is reconsidered: that tightening of the monetary policy in 1987?88 was delayed. This paper reveals that there exists a delay of monetary policy including actual tightening by interpreting the natural rate of interest (NRI) as measured from a DSGE model.

The call rate has remained continuously at a low level, very close to zero, because the Bank of Japan adopted a zero interest rate policy in 1999 and because it successively administered a quantitative easing policy in 2001. Dealing with such an economic situation in a DSGE model, as Eggertsson and Woodford (2003) have documented, it is necessary to impose a zero lower bound constraint that eliminates the negative policy rate proposed using a certain monetary policy rule. Therefore, a minor objective of this paper is to review results from the Bayesian estimated DSGE model without the zero lower bound constraint. Consequently, this paper presents the effect of zero interest rates, which cannot be ignored.

It is readily apparent that a macroeconomic model that enables forecasting of an economy and analyses of a policy's impact has been developed, but it has not reached its zenith of applicability. Considering future policy action, it is important to obtain an evaluation of past policy through empirical works based upon historical data. Estimation of a backward-looking macroeconomic model was done in a mainstream manner in previous studies. However, for policy analysis, these models are not included in the Lucas (1976) critique of reduced-form models: that they lack microfoundations.

Now that it is possible to use a dynamic stochastic general equilibrium (DSGE) model describing a national economy, the interest rate gap or the NRI estimated in the paper is consistent with a fully specified New Keynesian DSGE model, which is derived from optimization problem of households and firms. Moreover, using Bayesian techniques, the Bayesian-DSGE (B-DSGE) model, which is a point connecting theory with reality, is available for us.

Bayesian likelihood approaches have been used to estimate a fully specified DSGE model since Smets and Wouters (2003). The DSGE model in this paper resembles that which excludes the investment-specific technological progress from the Hirose and Kurozumi (2012) model. Sugo and Ueda (2008) and Fujiwara et al. (2011) also estimate the large-scale DSGE model with Bayesian techniques and Japan's aggregate time series data.

3.1 The Linearized DSGE Model

The DSGE model presented herein mostly follows that of Hirose and Kurozumi (2012). The estimated linearized DSGE model is presented in the next section. The dynamics of consumption, which follows from the consumption

Euler equation with respect to consumption and bond-holding, is given as

$$\hat{c}_t = \frac{1}{\Omega_2\Omega_3}\frac{\theta}{z}\hat{c}_{t-1} + \frac{1}{\Omega_3}\left(\frac{\beta\theta}{z^\alpha}\frac{1}{\Omega_1\Omega_2} + \frac{1}{\Omega_2} + \frac{\beta\theta}{z^\alpha}\frac{1}{\Omega_1\Omega_2}\frac{\theta}{z}\right)E_t\hat{c}_{t+1} - \frac{\beta\theta}{z^\alpha}\frac{1}{\Omega_1\Omega_2\Omega_3}E_t\hat{c}_{t+2}$$
$$- \frac{1}{\sigma}(\hat{R}_t - E_t\hat{\pi}_{t+1} - r_t^N) \tag{3.1}$$

where $\hat{c}_t$ is consumption,$\hat{R}_t$ is nominal interest rate, and $\hat{\pi}_t$ is the inflation rate. $\Omega_1 \equiv 1 - \theta/z$, $\Omega_2 \equiv 1 - \beta\theta/z^\alpha$, $\Omega_3 \equiv 1/\Omega_2 + \beta\theta/z^\alpha(1/\Omega_1\Omega_2)(\theta/z) + 1/\Omega_2(\theta/z)$. Then the natural rate of interest $\hat{r}_t^N$ is defined as the following.

$$\hat{r}_t^N \equiv - \frac{\sigma}{\Omega_2\Omega_3}\frac{\theta}{z}z_t^z + \frac{\sigma}{\Omega_3}\left(\frac{\beta\theta}{z^\alpha} + \frac{1}{\Omega_2}\frac{\theta}{z} + 1\right)E_t z_{t+1}^z - \frac{\beta\theta}{z^\alpha}\frac{\sigma}{\Omega_1\Omega_2\Omega_3}E_t z_{t+2}^z$$
$$+ \frac{1}{\Omega_2\Omega_3}z_t^b - \frac{1}{\Omega_2\Omega_3}\left(\frac{\beta\theta}{z^\alpha} + 1\right)E_t z_{t+1}^b + \frac{\beta\theta}{z^\alpha}\frac{1}{\Omega_2\Omega_3}E_t z_{t+2}^b. \tag{3.2}$$

where z_t^b represents a preference shock.

Labor supplied by households is differentiated by a union, so that some monopoly power over wages exists. Such backgrounds result in an explicit wage equation and allow for the introduction of Calvo-style sticky nominal wages. Because of nominal wage stickiness and partial indexation of wages to inflation[1], real wages adjust only gradually to the desired wage as

$$\hat{w}_t - \hat{w}_{t-1} + \hat{\pi}_t - \gamma_w\hat{\pi}_{t-1} + z_t^z = \beta z^{1-\sigma}(E_t\hat{w}_{t+1} - \hat{w}_t + E_t\hat{\pi}_{t+1} - \gamma_w\hat{\pi}_t + E_t z_{t+1}^z)$$
$$+ \frac{1-\xi_w}{\xi_w}\frac{(1-\beta\xi_w z^{1-\sigma})\lambda^w}{\lambda^w + \chi(1+\lambda^w)}(\chi\hat{l}_t - \hat{\lambda}_t - \hat{w}_t + z_t^b) + z_t^w, \tag{3.3}$$

where $\hat{w}_t$ represents the real wage, $\hat{l}_t$ denotes labor, $\hat{\lambda}_t$ stands for the marginal utility of consumption, and z_t^w is a labor shock.

Aggregating the Cobb?Douglas production functions over intermediate good firms generates

$$\hat{y}_t = (1+\phi)\{(1-\alpha)\hat{l}_t + \alpha(\hat{u}_t + \hat{k}_{t-1} - z_t^z)\}, \tag{3.4}$$

where $\hat{k}_t$ represents capital, $\hat{u}_t$ is the utilization rate of capital, and z_t^z is a technology shock.

[1]See Hirose and Kurozumi (2012).

Each intermediate good firm produces a differentiated good of one kind by choosing a pair of capital and labor to minimize production cost. Because of Calvo-type price stickiness and partial indexation to lagged inflation of those prices that can not be reoptimized, as described in Smets and Wouters (2003), prices adjust sluggishly to their desired price. Profit maximization by price-setting firms gives rise to the following New Keynesian Phillips curve as

$$\hat{\pi}_t - \gamma_p \hat{\pi}_{t-1} = \beta z^{1-\sigma}(E_t \hat{\pi}_{t+1} - \gamma_p \hat{\pi}_t) + \frac{(1-\xi_p)(1-\beta\xi_p z^{1-\sigma})}{\xi_p} \hat{mc}_t + z_t^p, \tag{3.5}$$

where $\hat{mc}_t$ denotes the real marginal cost and z_t^p represents a cost-push shock.

As in Hirose and Kurozumi (2012), the capital service firm owns the entire stock of capital at the beginning of each period. It rents utilization-adjusted capital to intermediate goods firms. The optimality condition for profit maximization with respect to investment $\hat{i}_t$ yields:

As in Hirose and Kurozumi (2012), the capital service firm owns the entire stock of capital at the beginning of each period. It rents utilization-adjusted capital to intermediate goods firms. The optimality condition for profit maximization with respect to investment $\hat{i}_t$ yields

$$\frac{1}{\zeta}\{\hat{i}_t - \hat{i}_{t-1} + z_t^z + z_t^i\} = q_t + \frac{\beta z^{1-\sigma}}{\zeta}\{E_t \hat{i}_{t+1} - \hat{i}_t + E_t z_{t+1}^z + E_t z_{t+1}^i\}, \tag{3.6}$$

where z_t^i is an investment shock.

The monetary authorities follow a generalized Taylor rule by gradually adjusting the policy-controlled interest rate.

$$\hat{R}_t = \phi_r \hat{R}_{t-1} + (1-\phi_r)\left\{\frac{\phi_\pi}{4}\sum_{j=1}^{3}\hat{\pi}_{t-j} + \phi_y(\hat{y}_t - \hat{y}_t^*)\right\} + z_t^r \tag{3.7}$$

where $\hat{y}_t^*$ is the potential output and z_t^r is a monetary policy shock.

Equations (1)-(7) and just six equations – the capital accumulation, utilization rate, Tobin's q, real marginal cost, cost-minimizing condition, production function, and potential output – determine 13 endogenous variables. All seven persistent shocks $z_t^z, z_t^b, z_t^w, z_t^g, z_t^i, z_t^p$, and z_t^r follow stationary first-order autoregressive processes[2].

[2] z_t^g is an expenditure shock.

3.2 Bayesian estimation

Our estimation methodology resembles that of Smets and Wouters (2003). We use Dynare, which is a useful tool for conducting Bayesian estimation[3]. The Dynare toolbox derives the reduced-form representation of the DSGE model and automatically provides stability and eigenvalue analysis. Moreover, it enables us to conduct Bayesian estimation[4].

Details of prior distributions used in the paper are presented in Table 1. Choosing the prior distributions, we mostly follow the previous literature related to Japan ' s Bayesian estimation: Hirose and Kurozumi (2012). The last two columns in Table 1 report the posterior for the structural parameters.

The data used for estimation are the real output growth rate, the real consumption growth rate, real investment growth rate, real wage growth rate, hours worked, inflation rate, and nominal interest rate in Japan's economy[5]. Similarly to studies by Hirose and Kurozumi (2012) and other studies, all data were obtained at quarterly frequencies of 1980Q2 to 1991Q4. The end of the sample is determined to exclude the period of the zero nominal interest rate policy because this paper specifically examines monetary policy before the bubble burst.

3.3 Implication

Jinushi, Kuroki, and Miyao (2000) presumed that the average economy during 1975-85 was ideal and that the benchmark nominal policy rate arose from an ad-hoc policy rule. Furthermore, they examined the difference between the actual policy rate and the rule-based one. As described herein, unlike Jinushi, Kuroki, and Miyao (2000), who did not consider a desired economy existing every period by the B-DSGE model, this paper presents a specific examination of the gap separating the natural rate of interest and the actual policy rate.

Figure 1 depicts the interest rate gap defined as the difference between the *nominal* Call rate and the *nominal*-based NRI[6]. The shaded areas indicating recessions are dated by the Cabinet Office.

[3]The Dynare file is available from the author upon request.

[4]See An and Schorfheide (2007) for a detailed explanation of Bayesian estimation.

[5]See Hirose and Kurozumi (2012). However, different from Hirose and Kurozumi, the estimated potential output was not used herein.

[6]From the Fisher equation, the nominal based natural rate of interest here is equal

The monetary policy in 1987?88, broadly speaking, was in a position where the economy was stimulated beyond necessity. After the Plaza Accord of 1985, the rapid appreciation of the yen brought about recessionary effects, and because it affected the decline of the potential output, the natural rate of interest fell. Then, the Bank of Japan implemented monetary easing. Consequently, the Bank of Japan (BOJ) retained its stance of loosening monetary policy until the bubble burst. From Figure 1, although there exist some temporary positive gaps, monetary easing (the negative gap) is maintained for three periods. It is interesting that the maximum negative gap is in 1988Q1. Moreover, as shown in Table 1, although the policy response to the output gap was quite low ($\phi_y = 0.069$), the authority preferred stable inflation ($\phi_{pi} = 1.697$) and indexation to the past policy rate ($\phi_r = 0.458$). The salient implication is that the BOJ had not misunderstood the potential economy and that neither economic agent noticed it. Consequently, a delay of monetary policy easing is evident[7].

Because the BOJ would not raise the controlled policy rate, the discount rate, in 1987 immediately and dynamically, and instead pursued an easing monetary policy gradually, it cannot be ruled out that it exacerbated the bubble.

3.4 NRI and the zero lower bound

The Bank of Japan has maintained extremely low interest rates since 1999. After the bubble collapse, Japan ' s economy stagnated. Few policy-makers have had a hopeful view of the economy in spite of various policies by the government and the Bank of Japan designed for its recovery. Specifically, the Bank of Japan pursued two monetary policies to keep the Call rate low: its zero interest rate policy (February 1999 ? August 2000) and its quantitative easing policy (March 2001 ? July 2006).

It is necessary to take account of the negative policy rate calculated using the monetary policy rule when central banks follow a rule such as a Taylor rule. The Taylor rule determines a policy rate based on the prior policy rate, the output gap, and the inflation rate. Considering the periods of the

to the posterior mean of the two-sided smoothed estimate of the natural rate of interest adding the model-based expected inflation $E_t\pi_{t+1}$.

[7]Figure 1 also shows that the easy monetary policy in 1980 and 1981 used to ride out the recession caused by the second oil crisis in 1979 indicates negative gaps.

Japanese stagnation, because there existed both a negative output gap and a deflation rate for some years, the policy rate estimated from the Taylor rule must have been negative at those times. In this case, as in Eggertsson and Woodford (2003), indeed, monetary authorities have no choice but to set the policy rate to be zero. Therefore, in the DSGE model, it is necessary to include the mechanism to replace the negative policy rate to zero. It is designated as "the zero lower bound constraint".

Estimating the DSGE model without the zero lower bound constraint using Bayesian techniques, the estimated model parameters and other results can not be reliable. Actually, from Table 2, because of the zero lower bound, the authors of previous studies of the Japan's B-DGES models intentionally avoid using the following periods as sample periods: February 1999 - August 2000 and March 2001 - July 2006. Those periods respectively correspond to the zero interest rate policy and the quantitative easing policy.

Figure 2 displays estimates of the NRI in differing lengths of sample periods: 1980Q2 - 1998Q4 and 1980Q2 - 2010Q4. Specifically, the data shown in Figure 2 depict the deviation from the steady state of the real interest rate. Two NRIs are similar in the common sample period: 1980Q2 - 1998Q4. However, they differ in their degrees of respective deviation[8].

Table 3 shows the results of the Bayesian estimated parameters on two sample periods: 1980Q2 - 1998Q4 and 1980Q2 - 2010Q4. Generally, in Bayesian inference, it is noteworthy that the statistical significance is independent of the number of data samples. The elasticity of intertemporal substitution σ before the zero interest rate policy is low relative to the result from the full sample. With respect to the difference in the results of σ, if the growth trends in both sample periods are similar, the NRI estimated from the full sample data is higher than that of the short sample period. Moreover, in household demand, it is interpreted that household consumption demand through interest rate gap declines. Consequently, even when the Bank of Japan tries to affect household demand through the interest rate gap, the effect is slight. Considering the zero lower bound constraint must be justified.

Regarding other results of the estimated parameters in the full sample, first the steady states of the real interest rate and the trend growth are low,

[8]The figure captures two featured events: the Asian financial crisis and Japan's banking crisis in 1997 and the global financial crisis. These periods when the NRI is below the steady state continue for one year at least.

which reflects the long-run slump economy during the periods. Second, the persistent degree of the policy rate is high because the low interest rate policy continues to be taken consistently. Finally, the persistence of monetary policy shock is low, so the persistence of monetary policy shock is low. Therefore, the monetary policy is implemented with an objective of the continuation of low interest rate. It is interpreted that the effect of monetary policy through the policy rate has been lost. As a result, since 1999, the role of monetary policy changed in the economy. Therefore, to represent the capacity of central bank accurately in a DSGE model, the zero lower bound constraint should be imposed.

3.5 Conclusion

As described in this paper, the aim is to evaluate monetary policy of the late 1980s. Results show that the latent interest rate gap that Jinushi, Kuroki, and Miyao (2000) did not demonstrate that monetary policy was delayed at that time. Furthermore, the authority could not ascertain the potential condition of the economy. Monetary policy has remained consistently on the easing side from 1985.

It has become increasingly important to impose a zero lower bound constraint when the sample period is lengthened to estimate the Japan DSGE model with Bayesian technique. The estimated NRI is expected to be useful for monetary policy analysis in the future.

Table 3.1: Prior and posterior distributions of parameters

		Prior distribution		Posterior distribution	
Parameters	Descriptions	Distribution	Mean	Mean	90% interval
σ	risk aversion	Gamma	1.000	2.676	[2.017, 3.293]
θ	habit consumption	Beta	0.700	0.146	[0.070, 0.218]
χ	elasticity of labor supply	Gamma	2.000	3.848	[2.347, 5.320]
$1/\zeta$	elasticity of invst. adj. cost	Gamma	4.000	4.276	[1.638, 6.800]
ϕ	s.s. fixed cost	Gamma	0.075	0.072	[0.053, 0.091]
γ_w	wage indexation	Gamma	0.500	0.385	[0.014, 0.732]
ξ_w	a fraction of wage	Gamma	0.375	0.109	[0.038, 0.176]
γ_p	price indexation	Gamma	0.500	0.211	[0.001, 0.432]
ξ_p	a fraction of price	Gamma	0.375	0.697	[0.616, 0.773]
λ_p	s.s. price markup	Gamma	0.150	0.219	[0.109, 0.331]
ϕ_r	interest rate smoothing	Gamma	0.800	0.458	[0.282, 0.645]
ϕ_π	policy response of inflation	Gamma	1.700	1.697	[1.540, 1.854]
ϕ_y	policy response of output	Gamma	0.125	0.069	[0.024, 0.113]
ρ_z	persistence of technology	Beat	0.500	0.074	[0.015, 0.128]
ρ_b	persistence of preference	Beat	0.500	0.845	[0.757, 0.929]
ρ_i	persistence of investment	Beat	0.500	0.606	[0.395, 0.869]
ρ_g	persistence of extended demand	Beat	0.500	0.936	[0.902, 0.971]
ρ_w	persistence of wage markup	Beat	0.500	0.350	[0.081, 0.603]
ρ_p	persistence of price markup	Beat	0.500	0.835	[0.719, 0.958]
ρ_r	persistence of monetary policy	Beat	0.500	0.822	[0.715, 0.926]
σ_z	stdev. of technology	Inverse gamma	0.500	1.815	[1.455, 2.165]
σ_b	stdev. of preference	Inverse gamma	0.500	0.221	[0.128, 0.310]
σ_i	stdev. of investment	Inverse gamma	0.500	5.401	[2.738, 8.438]
σ_g	stdev. of extended demand	Inverse gamma	0.500	2.227	[1.807, 2.637]
σ_w	stdev. of wage markup	Inverse gamma	0.500	1.377	[0.967, 1.782]
σ_p	stdev. of price markup	Inverse gamma	0.500	0.277	[0.155, 0.392]
σ_r	stdev. of monetary policy	Inverse gamma	0.500	0.178	[0.144, 0.212]

Note: The paper follows the setting of prior distributions presented by Hirose and Kurozumi (2012).

Figure 3.1: Interest rate gap

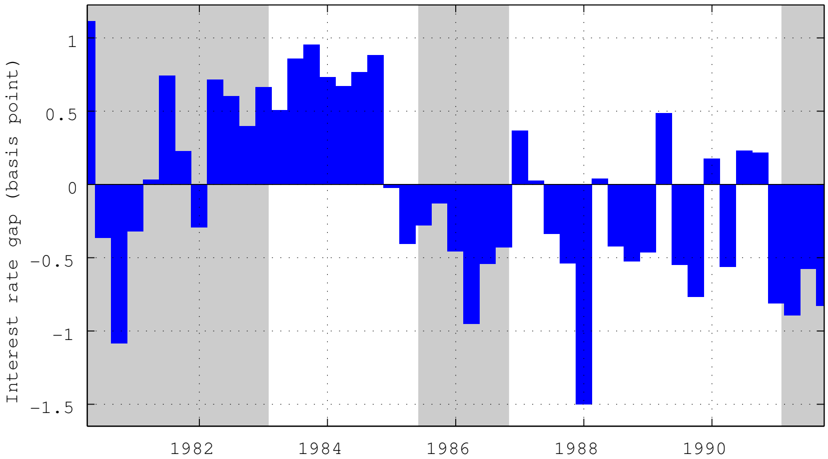
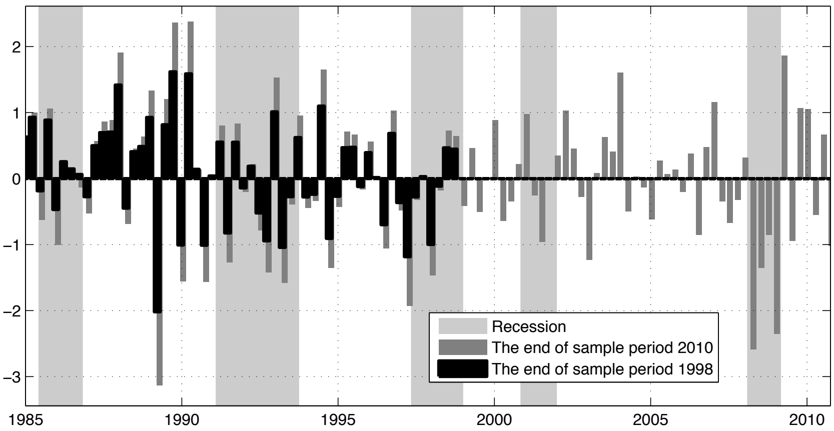


Figure 3.2: Natural rate of interest



Note: The Natural rate of interest shows the deviation from the steady state of the real interest rate.

Table 3.2: Parameter estimates

	1980Q2 - 1998Q4		1980Q2 - 2010Q4	
Parameters	Mean	90% interval	Mean	90% interval
σ	2.686	[2.024, 3.333]	3.025	[2.315, 3.712]
θ	0.098	[0.044, 0.147]	0.095	[0.048, 0.143]
r^*	0.570	[0.480, 0.655]	0.563	[0.481, 0.643]
z^*	0.161	[0.094, 0.225]	0.159	[0.098, 0.218]
ϕ_r	0.521	[0.374, 0.669]	0.686	[0.612, 0.762]
ρ_r	0.775	[0.655, 0.898]	0.657	[0.556, 0.759]

Chapter 4

Non-regular Workers and the Stagnant Economy

Since the bubble era, Japan's economy has not yet emerged from its long-run slump, which has lasted two decades. The development of *non-regular* workers is one noticeable feature that has produced the severely stagnated economy of that period. Figure 1 displays the transition of the share of non-regular workers among total labor (hereinafter, the *non-regular worker ratio*). Actually, the ratio was 17% in 1986 and was 34% in 2008, doubling over that period. In fact, one in three workers is a non-regular worker. Moreover, Figure 1 shows that, after 1990, the number of employees has remained mostly stable at 50 million, which emphasizes that a rise in the non-regular worker ratio is attributable simply to an increase in the number of non-regular workers.

In the 1980s, non-regular workers (often wives) were employees working to cover income that the main supporters (often husbands) earned. This surely meant that the income earned by non-regular workers was less than that of regular workers. However, during more than a decade after the bubble burst, circumstances by which the number of non-regular workers has increased can reflect that non-regular workers also play a role of the main supporters of their own households. If such households increase, then they are not able to support the same amount of consumption as flexibly as regular households might.

In Figure 2, it is readily apparent that the income of non-regular workers is below that of regular workers. As this figure shows, the medians are roughly estimated as around 0.8 million (Non-regular) and around 3.9 million

(Regular) in 2002, and to be around 1.2 million (Non-regular) and around 4.1 million (Regular) in 2007. What is the effect of such income inequality on both non-regular workers' consumption and regular workers' consumption? Presumably, no much difference exists between them in basic consumption in support of necessary expenditures (i.e., spending for food or clothing). However, non-regular workers who earn low income are unable to spend for housing investment or durable goods (i.e., automobile or home electronics) to the same degree as regular workers might. Non-regular workers can not afford to consume these additional goods aside from required fundamental consumption[1]: unless non-regular workers borrow additional funds from agents such as banks, they are unable to purchase these luxury goods and services. Actually, a high probability exists that they can not pass a bank's examination for borrowing because they are non-regular workers and are unable to prove a stable income.

To date, although the definition of non-regular workers has not been clear, non-regular workers and the causes of increasing non-regular worker employment are defined simply here. A sharp rise of non-regular workers has occurred not only in Japan but also in the United States, the United Kingdom, European countries, and Korea (Organization for Economic Co-operation and Development, 2002). Generally, non-regular workers are defined as workers who are not regular workers. However, studies by Suzuki (1999) point to a no single common definition of non-regular workers accepted worldwide.

Some definitions of non-regular workers exist in Japan because some government statistics capture non-regular workers[2]. Among them, the "Labour Force Survey", a survey of households usually residing in Japan, provides wide coverage of non-regular workers.

Based on the Labour Force Survey, the definitions of non-regular workers have three varieties. First, non-regular workers are those who work fewer hours than regular workers (fewer than 35 hours per week). Second, non-

[1]In January 2009, the Research Institute of Economy, Trade and Industry (RIETI) in Japan investigated employment of non-regular workers, especially dispatched workers, using web questionnaires. The web survey, 'Survey on life and job behavior of dispatched workers,' revealed that non-regular workers who are not able to save up money smoothly account for more than 70% of all non-regular workers.

[2]Statistical data on non-regular workers are issued by a few government ministries, for example, the Ministry of Internal Affairs and Communications and the Ministry of Health, Labour and Welfare.

regular workers are workers who are not designated as "regular employees" at work[3]. Finally, non-regular workers are those workers who have a job contract that expires within a year. The last definition is the same as the definition of 'temporary workers' defined by the OECD (Organization for Economic Co-operation and Development, 2002).

In this paper for Japan's economy, referring to the three definitions presented above, non-regular workers are defined as workers who work shorter hours than regular workers do. Especially, a dynamic general equilibrium model is constructed in which such non-regular workers appear at the later part of this paper, and the model built under the empirical evidence of aggregate time-series. For example, the model used for this study reflects the feature that regular workers work 1.73 times longer than non-regular workers in point of official working hours[4]. A firm that hires regular workers and non-regular workers chooses nonscheduled working hours to maximize its profit.

Empirical evidence of the causes of increasing use of non-regular workers has been widely documented by Cappelli and Neumark (2004), Comin and Mulani (2006), Comin and Philippon (2006), Ono and Sullivan (2006), Organization for Economic Co-operation and Development (2008), and Vidal and Tigges (2009). These studies have highlighted the swing of corporate performance. Especially, for Japan, Morikawa (2010) and Sano et al. (2011) showed that the reasons underlying increased use of non-regular workers correspond not to the industrial level but to the firm level. Furthermore, another factor from the firm level is that labor force of non-regular workers is gathered easily and labor costs are low. As in Autor et al. (2003) and Ikenaga (2009), such a factor causes firms to decrease regular workers and to hire non-regular workers, which almost work were simplified by information technology.

What impact does the increase in non-regular workers have on the real economy? Actually, many reports in the literature have described that expanding the non-regular worker ratio has had a negative effect on firm productivity in southern European countries[5] (i.e., Sanchez and Toharia, 2000, Dolado and Stucchi, 2008, and Boeri and Garibaldi, 2007). Oshima (2009) surveys details of the relation between non-regular workers and productivity.

[3] "Non-regular employees" are part-time employees, contract employees, fixed-term employees, and temporary employees.

[4] Based on Labor Force Survey, the average was calculated from 1990Q4 to 2008Q4.

[5] From OECD, 15.6% in 1987 → 35.0% in 1995 → 29.3% in 2008 in Spain. 4.8% in 985 → 12.5% in 2009 in Italy. 14.4% in 1986 → 22.0% in 2009 in Portugal.

No theoretical study described in the literature has examined non-regular workers who play a role as representatives of households. However, some studies specifically examine labor supply heterogeneity with housing investment. Eusepi and Preston (2009) and related studies portray a model comprising employed consumers and unemployed consumers. The model generates some empirical regularities using U.S. labor market data. The idea that family members of two types exist in the model economy, which these studies have highlighted, is adopted here. Moreover, Iacoviello (2005) and Monacelli (2009) studied a general equilibrium (new Keynesian) model that assumes that some households (borrowers) are subject to borrowing constraints by Kiyotaki and Moore (1997) to purchase housing or durable goods. This perspective is also adopted here. Adoption of a borrowing constraint can be justified from results of some empirical studies (Hayashi 1985 and 1987, Kohara and Horioka 1999) and will add to the borrowers some characteristics as non-regular workers.

The household types presented in this paper include non-regular workers and regular workers, not employed and unemployed people. This assumption reflects that the unemployment rate has remained stable during the past half decade: some non-regular workers are able to work for a year; others become unemployed temporarily. If this conjuncture arises every quarter, then the unemployment rate will be stable. Although many authors have specifically examined the sharp rise of non-regular workers empirically and have analyzed some theoretical model with unemployment, no study has introduced non-regular workers as one household type into a general equilibrium model that can explain the aggregate time-series evidence.

The paper is organized as follows. Section 2 presents some VAR evidence with the non-regular worker ratio. Section 3 presents the basic model. Section 4 analyzes its dynamics. Section 5 concludes the paper.

4.1 Empirical increasing non-regular worker shock

To assess the impact of a shock caused by increasing non-regular workers, we estimate Japan ' s quarterly VAR model specified as

$$\mathcal{Y}_t = \sum_{i=1}^{L} A_i \mathcal{Y}_{t-i} + B\epsilon_t \tag{4.1}$$

where ϵ_t is a vector of contemporaneous disturbances. Vector $\mathcal{Y}_t$ consists of four variables: (i) detrended TFP, (ii) detrended non-regular worker ratio (s), (iii) detrended real household consumption (Consumption), and (iv) detrended real housing investment (Housing), which represents real private residential investment. This composition includes all goods and services which non-regular workers are unable to obtain easily[6]. The VAR system is estimated over sample 1990Q4 - 2008Q4[7]. This VAR is used to document the key relations in the data. Figure 4 presents impulse responses of four variables to four identified shocks. Dashed lines represent 90-percent bootstrapped confidence bands.

1. A persistent response of the non-regular worker ratio to own shock;
2. To ratio shock, although not significantly, the negative responses of real aggregate consumption and housing investment;
3. The response of housing to a shock is greater than that of consumption; and
4. Neither positive nor negative response of the ratio to a positive technology shock.

These results are robust to the specifications of alternative ordering and fewer or additional lags. The remainder of the paper presents development of a model that is consistent with these facts.

[6]All data except the calculated TFP are available at the Statistics Bureau of the Ministry of Internal Affairs and Communications and the ESRI of the Cabinet Office

[7]TFP has already been detrended linearly. TFP is estimated based upon Kamada and Masuda (2001) and Kawamoto (2004), who adopted the *TANKAN* DI. The VAR system features a constant and two lags.

4.2 The model

Consider a discrete time, infinite horizon economy, populated by *entrepreneurs* and two types of households. The economy is composed of a continuum of households in the interval (0,1). There are two types of households, named *non-regular workers* and *regular workers*, of measure s and $1-s$, respectively. The two types of households (workers) have heterogeneous preferences that non-regular workers are more impatient than regular workers. The term "patient" captures the assumption that non-regular workers have lower discount rates than regular workers and firms[8]. Entrepreneurs produce a homogenous good, hiring two types of household labor[9]. Households consume, work, and demand housing investment. That is, all households derive utility from consumption of a final good and from possessing housing services. In addition, there are *retailers* and a *central bank*. Retailers are the source of nominal rigidity. The central bank adjusts the short-term nominal interest rate.

Considering a discrete time, infinite horizon economy, populated by *entrepreneurs* and households of two types, this economy comprises a continuum of households in the interval of (0,1). Two types of households exist, respectively designated as *non-regular* workers and *regular* workers, of measure s and $1-s$. The households (workers) of two types have heterogeneous preferences by which non-regular workers are more impatient than regular workers. The term "patient" reflects the assumption that non-regular workers have lower discount rates than regular workers and firms[10]. Entrepreneurs produce a homogeneous good, hiring household labor of two types[11]. Households consume, work, and demand housing investment: all households derive

[8]For earlier models with heterogeneity in discount rates, see Becker (1980), Kiyotaki and Moore (1997), Iacoviello (2005), Campbell and Hercowitz (2006), and Monacelli (2009).

[9]I will not assume that a non-regular worker get promoted to regular worker or a regular get demoted to non-regular worker unfortunately. Especially, the assumption of the non-switch from a non-regular to a regular worker is justified from 'General Survey on Temporary Workers' Contract 2009/2011' by Ministry of Health, Labour and Welfare (in Japanese only).

[10]For earlier models with heterogeneity in discount rates, see Becker (1980), Kiyotaki and Moore (1997), Iacoviello (2005), Campbell and Hercowitz (2006), and Monacelli (2009).

[11]A non-regular worker is not assumed to be promoted to regular worker or a regular to be demoted to non-regular worker unfortunately. Especially, the assumption of the non-switch from a non-regular to a regular worker is justified from ' General Survey on Temporary Workers ' Contract 2009/2011 ' by Ministry of Health, Labour and Welfare (in Japanese only).

utility from consumption of a final good and from possessing housing services. In addition, *retailers* and a *central bank* exist. Retailers are the source of nominal rigidity. The central bank adjusts the short-term nominal interest rate.

4.2.1 Non-regular worker households

As described above, the existence of non-regular workers is identified here in point of hours worked. Working hours for both non-regular and regular workers are composites of scheduled and nonscheduled hours. As the data show, regular workers work 1.73 times as long as non-regular workers in point of official working hours; then their scheduled hours are assumed to be constant. For workers of both types, nonscheduled hours are chosen by firms in view of the corporate performance and are assumed to be varying.

If the assumptions described above are fully adopted, then non-regular worker households maximize the following utility program:

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta_N^t U(c_{N,t}, \mathbb{C}_{t-1}, h_{N,t}, \mathbb{H}_{t-1}, L_{c,t}^N, L_{h,t}^N) \right\} \tag{4.2}$$

$$\begin{aligned} &U(c_{N,t}, \mathbb{C}_{t-1}, h_{N,t}, \mathbb{H}_{t-1}, L_{c,t}^N, L_{h,t}^N) \\ &= \ln(c_{N,t} - f_c \mathbb{C}_{t-1}) + j \ln(h_{N,t} - f_h \mathbb{H}_{t-1}) - \frac{1}{1+\eta_N} \left\{ (L_{c,t}^N)^{1+\epsilon_N} + (L_{h,t}^N)^{1+\epsilon_N} \right\}^{\frac{1+\eta_N}{1+\epsilon_N}} \end{aligned}$$

where household utility depends on the lagged aggregate consumption and housing and housing investment, defined as

$$\begin{aligned} \mathbb{C}_t &= (1 - s_t) \times c_{R,t} + s_t \times c_{N,t}, \\ \mathbb{H}_t &= (1 - s_t) \times h_{R,t} + s_t \times h_{N,t}, \end{aligned}$$

and

$$L_{c,t}^N = \bar{L}_{c,N} + L_{cN,t}, \tag{4.3}$$

$$L_{h,t}^N = \bar{L}_{h,N} + L_{hN,t} \tag{4.4}$$

subject to the sequence of budget constraints (in nominal terms):

$$P_t c_{N,t} + Q_t(h_{N,t} - (1-\delta_h) h_{N,t-1}) + R_{t-1} B_{N,t-1} + \Xi_{hN,t} = B_{N,t} + W_{cN,t} L_{c,t}^N + W_{hN,t} L_{h,t}^N, \tag{4.5}$$

where E_0 is the expectation operator, $\beta_N \in (0,1)$ is discount factor, $c_{N,t}$ is consumption at t, $h_{N,t}$ denotes the holding of housing, $L^N_{c,t}$ and $L^N_{h,t}$ are total hours worked for consumption goods and housing investment respectively, $\bar{L}_{c,N}$ and $\bar{L}_{c,N}$ are constant scheduled working hours for each sector, $L_{cN,t}$ and $L_{cN,t}$ are variable nonscheduled working hours, Q_t is the nominal housing price, $B_{N,t-1}$ is end-of-period t nominal one period debt, R_{t-1} is the nominal interest rate on loan between $t-1$ and t, $W_{N,t}$ is the nominal wage, and $\Xi_{hN,t}$ is nominal adjustment cost for housing, which is symmetric for each agent.

In real terms, (3) reads

where E_0 stands for the expectation operator, $\beta_N \in (0,1)$ denotes a discount factor, $c_{N,t}$ signifies consumption at t, $h_{N,t}$ denotes the holding of housing, $L^N_{c,t}$ and $L^N_{h,t}$ respectively represent total hours worked for consumption goods and housing investment, $\bar{L}_{c,N}$ and $\bar{L}_{c,N}$ respectively denote constant scheduled working hours for each sector, $L_{cN,t}$ and $L_{cN,t}$ are variable nonscheduled working hours, Q_t is the nominal housing price, $B_{N,t-1}$ is the end-of-period t nominal one period debt, R_{t-1} is the nominal interest rate on loan between $t-1$ and t, $W_{N,t}$ represents the nominal wage, and $\Xi_{hN,t}$ is the nominal adjustment cost for housing, which is symmetric for each agent.

In real terms, (3) reads

$$c_{N,t} + q_t(h_{N,t} - (1-\delta_h)h_{N,t-1}) + \frac{R_{t-1}}{\pi_t} b_{N,t-1} + \xi_{hN,t} = b_{N,t} + w_{cN,t}L^N_{c,t} + w_{hN,t}L^N_{h,t}, \tag{4.6}$$

where

$$\xi_{N,t} = \frac{\phi_h}{2\delta_h}\left(\frac{h_{N,t} - (1-\delta_h)h_{N,t-1}}{h_{N,t-1}} - \delta_h\right)^2 q_t h_{N,t-1}, \tag{4.7}$$

and $\xi_{N,t}$ is the real adjustment cost for housing. In addition, $q_t \equiv \frac{Q_t}{P_t}$ stands for the real housing price, $\pi_t \equiv \frac{P_t}{P_{t-1}}$ signifies the gross inflation rate, $b_{N,t-1} \equiv \frac{B_{N,t-1}}{P_t}$ denotes the real debt, and $w_{cN,t} \equiv \frac{W_{cN,t}}{P_t}$ and $w_{hN,t} \equiv \frac{W_{hN,t}}{P_t}$ respectively represent the real wages in sectors of consumption goods and housing investment.

As in Kiyotaki and Moore (1997), a limit is assumed on the obligations of non-regular workers: if the borrowers deny the call from lenders, then the lenders can repossess not the expected complete future value of the housing but a fraction of the value. The borrowers' assets are equal to lenders' collections after depreciation and paying a proportional transaction cost: $mE_t\left(q_{t+1}\left(1-\delta_h\right)h_{N,t}\right),\ 0 < m < 1$. In other words, the value $mE_t\left(q_{t+1}\left(1-\delta_h\right)h_{N,t}\right)$ is equal to the value of collateral. Finally, the maximum amount $R_tB_{N,t}$ that a creditor can borrow is set as below in real terms:

$$R_tb_{N,t} \leq mE_t\left(q_{t+1}\left(1-\delta_{h}.\right)h_{N,t}\pi_{t+1}\right). \tag{4.8}$$

Assuming that the collateral constraint (8) is always satisfied with equality in and around the steady state, Equation (8) can be expressed in real terms as

$$R_tb_{N,t} = mE_t\left(q_{t+1}\left(1-\delta_{h}.\right)h_{N,t}\pi_{t+1}\right). \tag{4.9}$$

4.2.2 Regular worker households

Aside from non-regular workers, the economy comprises a type of household that offers regular workers. They have already turned up in the dynamic optimization literature as representative agents. Non-regular workers discount the future more heavily than regular workers do: regular workers correspond to patient workers characterized in previous studies.

Moreover, as in previous subsections, regular workers are identified as workers of the opposite to non-regular workers: the official hours are longer than the non-regular worker hours.

If the assumptions described above are fully adopted, then regular workers maximize the following utility program:

$$E_0\left\{\sum_{t=0}^{\infty}\beta_R^tU(c_{R,t},\mathbb{C}_{t-1},h_{R,t},\mathbb{H}_{t-1},L_{c,t}^R,L_{h,t}^R)\right\} \tag{4.10}$$

$$\begin{aligned}&U(c_{R,t},\mathbb{C}_{t-1},h_{R,t},\mathbb{H}_{t-1},L_{c,t}^R,L_{h,t}^R)\\&=\ln(c_{R,t}-f_c\mathbb{C}_{t-1})+j\ln(h_{R,t}-f_h\mathbb{H}_{t-1})-\frac{1}{1+\eta_R}\left\{(L_{c,t}^R)^{1+\epsilon_R}+(L_{h,t}^R)^{1+\epsilon_R}\right\}^{\frac{1+\eta_R}{1+\epsilon_R}}\end{aligned}$$

for which the following are true:

$$L_{c,t}^R = \bar{L}_{c,R}+L_{cR,t}, \tag{4.11}$$
$$L_{h,t}^R = \bar{L}_{h,R}+L_{hR,t}. \tag{4.12}$$

Those expressions are subject to the sequence of budget constraints (in real terms) as

$$c_{R,t} + q_t(h_{R,t} - (1-\delta_h)h_{R,t-1}) + \frac{R_{t-1}}{\pi_t} b_{R,t-1} + \xi_{hR,t} = b_{R,t} + w_{cR,t}L^R_{c,t} + w_{hR,t}L^R_{h,t} + F_t, \tag{4.13}$$

where

$$\xi_{R,t} = \frac{\phi_h}{2\delta_h}\left(\frac{h_{R,t} - (1-\delta_h)h_{R,t-1}}{h_{R,t-1}} - \delta_h\right)^2 q_t h_{R,t-1}, \tag{4.14}$$

for which $\xi_{R,t}$ is the real adjustment cost for housing, F_t denotes lump-sum profits received from the retailers (described below), and $\beta_N < \beta_R$. The latter assumption guarantees an equilibrium in which non-regular workers will hit the borrowing constraint.

4.2.3 Entrepreneurs of intermediate consumption goods

Entrepreneurs produce intermediate consumption goods, which are differentiated and which face perfect competition. They hire workers of two types (non-regular and regular workers) as labor inputs $L_{N,t}$ and $L_{R,t}$ and they have access to a production function in producing intermediate goods:

$$Y_{c,t} = A_{c,t}\left[\left(L^R_{c,t}\right)^{(1-a_{c,t})}\left(L^N_{c,t}\right)^{a_{c,t}}\right]^{\mu_c} \tag{4.15}$$

and equivalently

$$a_{c,t} = \frac{w_{cN,t}L^N_{c,t}}{w_{cN,t}L^N_{c,t} + w_{cR,t}L^R_{c,t}}$$

where $A_{c,t}$ denotes productivity and obeys the AR(1) process[12], which does not affect the non-regular worker ratio as a result of empirical examination, parameter μ_c is the labor income share for intermediate goods, and s_t is the time-varying ratio of non-regular workers and obeys AR(1) process. Finally, entrepreneurs maximize their own profits as Π_t, subject to Equations (15) and (16).

$$\Pi_{c,t} = \frac{Y_{c,t}}{X_t} - (w_{cR,t}L^R_{c,t} + w_{cN,t}L^N_{c,t})$$

[12]From empirical evidence presented in previous sections, one assumes that technology is unrelated to the non-regular worker ratio directly.

4.2.4 Retailers

To introduce the source of nominal stickiness in the model economy, Bernanke et al. (1999) is followed, with the assumption that monopolistic competition occurs at the "retail" level. Final good Y_t^F is a CES composite of a continuum of mass unity of differentiated retailers, indexed by z. They purchase intermediate outputs from entrepreneurs at P_t^E and use them as the sole input. Total final goods are the following composite of individual retail goods:

$$Y_t^F = \left[\int_0^1 Y_t(z)^{(\epsilon-1)/\epsilon} dz\right]^{-\epsilon/(\epsilon-1)}, \tag{4.16}$$

with $\epsilon > 1$. The corresponding price index is given by

$$P_t = \left[\int_0^1 P_t(z)^{(1-\epsilon)} dz\right]^{1/(1-\epsilon)}. \tag{4.17}$$

Therefore, each retailer faces an individual demand curve:

$$Y_t(z) = \left(\frac{P_t(z)}{P_t}\right)^{-\epsilon} Y_t^F. \tag{4.18}$$

The retailer choose the sale price $P_t(z)$, taking as given the demand curve and the price of wholesale goods, P_t^w.

To introduce nominal rigidities, a retailer can adjust its price freely with probability $1-\theta$, following Calvo (1983). Letting $P_t^*(z)$ be the "reset" price set by retailers who are able to revise their prices at period t, and letting $Y_t^*(z)$ be the demand at this price, then the retailer chooses a price to maximize the expected discounted profit, given as

$$\sum_{t=0}^{\infty} \theta^k E_t \left[\Lambda_{t,k} \left(\frac{P_t^*(z) - P_{t+k}^w}{P_{t+k}}\right) Y_{t+k}^*(z)\right], \tag{4.19}$$

where $\Lambda_{t,k} \equiv \beta(c_{R,t}/c_{R,t+k})$ is the regular worker household relevant discount factor.

Differentiating the objective with respect to P_t^*, the optimal price has to satisfy the following condition of

$$\sum_{t=0}^{\infty} \theta^k E_t \left[\Lambda_{t,k} \left(\frac{P_t^*(z)}{P_{t+k}} - \frac{X}{X_{t+k}}\right) Y_{t+k}^*(z)\right] = 0, \tag{4.20}$$

where $X_t(\equiv P_t/P_t^w)$ is the markup, which equal to $X^* = \epsilon/(\epsilon - 1)$ in steady state. As in BGG and Iacoviello (2005), this condition states that P_t^* equates the expected discounted marginal revenue to the expected discounted marginal cost. Given that the fraction θ of retailers do note change their price in period t, the aggregate price evolves according to

$$P_t = [\theta P_{t-1}^{1-\epsilon} + (1-\theta)'(P_t^*)^{1-\epsilon}]^{1/(1-\epsilon)}. \tag{4.21}$$

By combining Equation (22) and (23), and then log-linearizing, it is possible to yield a forward-looking Phillips curve.

4.2.5 Housing producers

In a competitive flexible price market, new homes are produced with labor only and without productivity. The production technology is

$$Y_{h,t} = \left[\left(L_{h,t}^R\right)^{(1-a_{h,t})}\left(L_{h,t}^N\right)^{a_{h,t}}\right]^{\mu_h} \tag{4.22}$$

and equivalently

$$a_{h,t} = \frac{w_{hN,t}L_{h,t}^N}{w_{hN,t}L_{h,t}^N + w_{hR,t}L_{h,t}^R}.$$

Housing producers solve the following maximization to hire labor:

$$\Pi_{h,t} = q_t Y_{h,t} - (w_{hR,t}L_{h,t}^R + w_{hN,t}L_{h,t}^N).$$

4.2.6 Central bank

Monetary policy is conducted using a simple Taylor-type rule as

$$R_t = (R_{t-1})^{\gamma_R}\left(\pi_{t-1}^{1+\gamma_\pi}(Y_{c,t-1}^F/Y_{c,t-1})^{\gamma_x}R^*\right)^{1-\gamma_R}\epsilon_{R,t} \tag{4.23}$$

where R^* denotes the steady state real interest rate, Y_{t-1}^F is the final output (total demand) by retailer, and Y_{t-1}^N stands for the natural rate of output. In addition, $\epsilon_{R,t}$ is a policy shock assumed to have zero mean, with variance σ_{ϵ_R}.

4.2.7 Market clearing

The market clearing conditions are given by the following:

$$\mathbb{C}_t = (1 - s_t) \times c_{R,t} + s_t \times c_{N,t}, \tag{4.24}$$

$$\mathbb{H}_t = (1 - s_t) \times h_{R,t} + s_t \times h_{N,t}, \tag{4.25}$$

$$Y^F_{c,t} = \mathbb{C}_t, \tag{4.26}$$

$$Y_{h,t} = (1 - s_t)(h_{R,t} - (1 - \delta_h)h_{R,t-1}) + s_t(h_{N,t} - (1 - \delta_h)h_{N,t-1}), \tag{4.27}$$

$$0 = (1 - s_t) \times b_{R,t} + s_t \times b_{N,t}, \tag{4.28}$$

$$Y^F_{c,t} = D_t \times Y_{c,t}, \tag{4.29}$$

and finally,

$$D_t = \theta D_{t-1}\pi_t^{\alpha} + (1 - \theta)\left(\frac{1 - \theta\pi_t^{\theta-1}}{1 - \theta}\right)^{-\frac{\alpha}{1-\theta}}. \tag{4.30}$$

In those equations, $\mathbb{C}_t$ represents the total spending for consumption, $\mathbb{H}_t$ stands for the total spending for housing investment, and D_t denotes price dispersion[13]. Equations (19)-(24) respectively represent the goods market, the total household consumption, the borrowing?lending relation, resource constraint for real estate, the linkage between wholesale and retail output, and the price dispersion form.

4.2.8 Deterministic steady state

In the deterministic steady state, inflation π^* is assumed as one. Therefore, R^* corresponds to the real interest rate. It is equal to the reciprocal of the regular workers' discount rate $1/\beta_R$ from their consumption Euler condition. Because of the assumption that the regular workers' discount rate is greater than the non-regular workers' discount rate, $\beta_N < \beta_R$. In this case, it is necessary to verify that the debt of non-regular workers is always positive. It is possible to evaluate (8) in the steady state and obtain

$$\frac{b^*_N}{Y^*} = m(1 - \delta_h)\beta_R\{f_h\Omega_{5R} + \Omega_{1N}(\Omega_{5N} - f_c)\} \tag{4.31}$$

[13]See Gertler and Karadi (2010).

where

$$\Omega_{1N} = \frac{j(1-\beta_N f_h s^*)}{\{1-\beta_N(1-\delta_h)-(\beta_R-\beta_N)m(1-\delta_h)\}(1-f_c s^*)} > 0, \quad (4.32)$$

and where Ω_{5R} and $\Omega_{5N} > 0$ respectively represent the steady state of housing price and consumption for non-regular workers[14]. The steady-state debt for regular workers $\frac{b_R^*}{Y^*}$ is always negative $-\frac{s^*}{1-s^*}\frac{b_N^*}{Y^*}$ and corresponds to saving. It is particularly interesting that the amount of saving that regular workers need to prepare for non-regular workers' loans depends on the steady-state non-regular worker ratio s^*, i.e., if the steady state s^* is set to 0.34, a regular worker saves half the amount which a non-regular worker borrows, whereas a regular worker must save more than the required amount by a regular worker when $s^* > 0.50$.

4.2.9 Calibration and solution method

Some parameters are calibrated based on the data sample means and other studies. The steady-state real rate of interest is set as $R^* = 1.5$. Then, because it is pinned down by the regular workers' discount rate, this setting implies that $(1/\beta_R)^4 = 1.015$, and in turn that $\beta_R = 0.996$. The non-regular worker's discount rate was set as $\beta_N = 0.95$. Next, the parameters η_R, η_N, e_R, and e_N, specifying the disutility of labor, were set respectively to 3.00, 2.00, 0.40, and 0.80[15]. The non-regular worker "loan-to-value" ratio m is set to 0.50 initially. Finally, as in Iacoviello (2005), the parameters j are set to 0.10.

The existence of non-regular workers can be specified further. When scheduled hours worked for regular workers in the market of consumption goods $\bar{L}_{c,R}$ is valued as 1.28, from the empirical result that scheduled working hours for regular workers are 1.73 times as great as those of non-regular workers, non-regular workers' scheduled hours $\bar{L}_{c,N}$ were set to 0.73 (=1.28/1.73). Similarly, if scheduled hours worked for regular workers in the market of housing are valued as 0.13, then non-regular workers' scheduled hours $\bar{L}_{h,N}$ are 0.08. As economy-wide parameters, an annual depreciation rate for housing is chosen as 0.04 percent: $\delta_h = 0.01$. Furthermore, the habit parameters f_c and f_h are set respectively to 0.11 and 0.00.

[14]See Appendix for more information.
[15]These settings follow Horvath (2000).

As firms' parameters, the income share of consumption goods μ_c, and the income share of housing μ_h were set respectively to 0.63, and 0.70. The elasticity α is 30. The degree of nominal rigidity to generate a frequency of price adjustment of about eight quarters is the probability of not resetting prices θ. Following Sugo and Ueda (2008), who estimated Japan's Bayesian DSGE model, θ equals 0.87. Moreover, the elasticity of substitution of intermediate goods ϵ is set to 5, implying a steady state mark-up $X^*(=\frac{\epsilon}{\epsilon-1})$ of 25%. For the steady state ratio of non-regular workers s^*, it was set to 0.34, which results from the data sample mean. Finally, for the Taylor rule, as in Sugo and Ueda (2008), the following were set: $\gamma_x = 0.11$, $\gamma_\pi = 0.60$, and $\gamma_R = 0.84$.

The solution methods consist in taking a log-linear approximation of the equilibrium conditions in the neighborhood of the deterministic steady state. Dynare was used, which derives the reduced form representation of the DSGE model and which automatically provides stability and eigenvalue analysis.

4.3 Simulation results

4.3.1 Baseline responses

It is straightforward to demonstrate the ability to produce an empirically plausible response to non-regular worker ratio shock. Figures 6 and 7 display the impulse responses of selected variables to a persistent ratio shock [16]. These variables are selected as macroeconomic variables described in Section II. Figures show the responses of ten key variables: aggregate consumption, housing investment, output for consumption, output for housing investment, inflation, the output gap, nominal interest rate, housing prices, savings, and borrowing.

consumption goods

Aggregate consumption (i.e. consumption goods) is examined first. Particularly the impact elasticity of consumption to a 10-percent increase in the non-regular worker ratio is around -0.02. This result, in terms of shape, is close to the empirical value. This arises from the realization that the ratio shock has persistence.

[16] It is a 10 basis points innovation

This picture highlights the reason underlying the success of the model in tracking down the empirical negative elasticity of spending to ratio. To better understand the result, it is useful to interpret that the figures exhibit responses of each type of worker (non-regular and regular worker). As described in Section 2, s can relate to the share of non-regular worker ' s wage. Therefore, one can presume that if s goes up, then income for non-regular worker rises and non-regular worker can consume more consumption goods so that income for non-regular workers rises. However, such a mechanism by which non-regular workers ' income rises seems not to be at work in the model[17]. The top left and right in Figure 8 display the impulse responses of consumption by regular workers (right) and non-regular workers (left) to the ratio shock. The rise in the non-regular ratio reduces the regular worker ' s consumption and increases the non-regular worker ' s consumption. The two responses go in opposite directions, and for a scale of impact, the latter reaction is much greater than the former. Therefore, aggregate consumption declines because the negative effects of both regular workers and ratio itself are dominant.

Details of the mechanism underlying each worker ' s consumption can be discussed. Therefore, it is useful to reinterpret the linearized optimality condition between the ratio and consumption. For instance, for regular workers, it can be written as

$$\begin{aligned}\hat{c}_{R,t} = {} & \mathcal{C}_{R,-1}\hat{c}_{R,t-1} + \mathcal{C}_{R,+1}E_t\hat{c}_{R,t+1} - \mathcal{C}_{R,+2}E_t\hat{c}_{R,t+2} + \mathcal{C}_{N,-1}\hat{c}_{N,t-1} - \mathcal{C}_{N,0}\hat{c}_{N,t} \\ & + \mathcal{C}_{N,+1}E_t\hat{c}_{N,t+1} - \mathcal{S}_{R,-1}\hat{s}_{t-1} + \mathcal{S}_{R,0}\hat{s}_t - \mathcal{S}_{R,+1}E_t\hat{s}_{t+1} - \mathcal{R}(\hat{R}_t - E_t\pi_{t+1}),\end{aligned} \tag{4.33}$$

where

$$\mathcal{C}_{R,-1}, \mathcal{C}_{R,0}, \mathcal{C}_{R,+1}, \mathcal{C}_{R,+2}, \mathcal{C}_{N,-1}, \mathcal{C}_{N,0}, \mathcal{C}_{N,+1}, \mathcal{S}_{R,-1}, \mathcal{S}_{R,0}, \mathcal{S}_{R,+1}, \mathcal{R} > 0.$$

This equation clearly illustrates that, keeping consumption in regular and non-regular cases, immediately after the shock, the effect of expected non-regular worker ratio is negative and large. Thereafter, by adding to the effect of past ratio, the negative effect on regular worker ' s consumption expands well. Moreover, this equation is reinterpreted as a demand equation for consumption goods based on the intertemporal work style, which means that the negative sign of the term s_{t-1} is the memory of a past event, that

[17] Full details will be explained later in Section 4.2.

the positive sign of the term s_t is a relief that a present ratio s_t is exactly lower than past ratio s_{t-1}, and that the negative sign of the term s_{t+1} signifies anxiety about an increasing ratio.

Regarding the response of output for consumption goods after shock, it shows the same characteristics of response as aggregate consumption does (bottom left in Figure 6). However, the output gap is slightly positive and hump-shaped. Moreover, the reaction of inflation is sharply negative, but inflation is not negative and the sale price does not fall in terms of a deviation from the steady state because the steady state of inflation is assumed to be 1. From the Taylor rule assumption, the nominal interest rate depends mainly upon the interest rate inertia (middle left in Figure 7).

Let me think of the mechanism behind these results ($\pi < 1$ and $\pi \approx 1$ and $x > 0$), referring to Figure 4 that displays the supply-demand relationship between retailers and wholesalers (entrepreneurs)[18]. Assuming the steady state before shock express a point E in the figure, the results for both retailers and wholesalers as their reactions to a shock stands for the points M and N respectively. With respect to each response of price and quantity, as I described, since (retail price) inflation is strictly close to 1% but less than 1%, retail price goes up from the steady state price, and from Equation (18), intermediate goods demanded (final goods supplied) by retailers decline. Meanwhile, in order to generate the positive output gap, the output by wholesalers decreases more than the retailers' one. Hence, wholesale price is lower than the steady state price for wholesalers. This means that the mark-up X_t ($\equiv p_t/p_t^w$) rises and that it consistently causes inflation down according to NKPC $\hat{\pi}_t = \beta_R \hat{\pi}_{t-1} - \kappa \hat{X}_t$.

The mechanism underlying these results ($\pi < 1$ and $\pi \approx 1$ and $x > 0$) can be inferred by referring to Figure 4, which displays the supply demand relation between retailers and wholesalers (entrepreneurs)[19]. Assuming the steady state before shock express a point E in the figure, the results for both retailers and wholesalers as their reactions to a shock stands respectively for points M and N. With respect to each response of price and quantity, as described earlier, because (retail price) inflation is strictly close to 1% but less than 1%, the retail price increases from the steady state price, and

[18]In the paper, I consider that the goods supplied to households are different with the goods produced by retailers. Therefore, a vertical axis in the figure stands for two kinds of price.

[19]The goods supplied to households differ from goods produced by retailers. Therefore, a vertical axis in the figure stands for prices of two kinds.

from Equation (18), intermediate goods demanded (final goods supplied) by retailers decline. To generate the positive output gap, the output by wholesalers decreases more than the retailers' output. Therefore, wholesale prices are lower than the steady state price for wholesalers. The mark-up X_t ($\equiv p_t/p_t^w$) rises. It consistently brings inflation down according to NKPC $\hat{\pi}_t = \beta_R \hat{\pi}_{t-1} - \kappa \hat{X}_t$.

housing investment

The top right area of Figure 6 displays the response of aggregate housing investment to a ratio shock. The increase in the ratio reduces aggregate housing investment as well as aggregate consumption. The effect of a ratio shock keeps 1 percent persistently, even at 20 quarters after shock. To ascertain the mechanism behind this result, it is necessary to estimate each response of both regular and non-regular workers to a change in ratio. The bottom right and left in Figure 8 display a positive reaction of non-regular workers' housing investment and a negative reaction of regular workers to the shock. Although the figures in this paper display the responses of model variables until 20 quarters, for instance, the peak response of non-regular workers' housing investment reaches 7.33% at 29 quarters after a shock, and the response of regular workers comes up to -0.16% at 32 quarters. Both responses persistently maintain a situation in which the variables deviate from the steady states.

As in the case of aggregate consumption, the demand equation must be shown for housing investment for a regular worker. Housing investment can be expressed as the following:

$$
\begin{aligned}
\hat{h}_{R,t} = & -\mathcal{H}_{c_R,-1}\hat{c}_{R,t-1} - \mathcal{H}_{c_R,0}\hat{c}_{R,t} + \mathcal{H}_{c_R,+1}\hat{c}_{R,t+1} + \mathcal{H}_{c_R,+2}\hat{c}_{R,t+2} - \mathcal{H}_{c_N,-1}\hat{c}_{N,t-1} \\
& + \mathcal{H}_{c_N,0}\hat{c}_{N,t} + \mathcal{H}_{c_N,+1}\hat{c}_{N,t+1} + \mathcal{H}_{R,-1}\hat{h}_{R,t-1} + \mathcal{H}_{R,+1}\hat{h}_{R,t+1} + \mathcal{H}_{N,-1}\hat{h}_{N,t-1} \\
& - \mathcal{H}_{N,0}\hat{h}_{N,t} + \mathcal{S}_{R,-1}\hat{s}_{t-1} - \mathcal{S}_{R,0}\hat{s}_t + \mathcal{S}_{R,+1}\hat{s}_{t+1} \qquad (4.34)
\end{aligned}
$$

where

$$
\begin{aligned}
& \mathcal{H}_{c_R,-1}, \mathcal{H}_{c_R,0}, \mathcal{H}_{c_R,+1}, \mathcal{H}_{c_R,+2}, \mathcal{H}_{c_N,-1}, \mathcal{H}_{c_N,0}, \mathcal{H}_{c_N,+1}, \mathcal{H}_{R,-1}, \mathcal{H}_{R,+1}, \mathcal{H}_{N,-1}, \\
& \mathcal{H}_{N,0}, \mathcal{S}_{R,-1}, \mathcal{S}_{R,0}, \mathcal{S}_{R,+1} > 0
\end{aligned}
$$

This equation illustrates clearly that, keeping other terms constant except for the term of the ratio, the current term of ratio on $h_{R,t}$ has a dominant negative effect. Moreover, according to the characteristic of housing that it has durability, i.e., that it is not completely consumed in one period, regular workers need not increase housing at the current period after shock s_t and are able to support their housing demand from s_{t-1} and $E_t s_{t+1}$.

As in the case of aggregate consumption, the positive response of non-regular workers' housing demand is apparently caused by a change in their income. In the sector of housing production, as assumed for simplicity, an increase in ratio can mean that the income share of regular workers changes negatively. Therefore, non-regular workers generally earn more from a housing sector and add to housing investment. However, the results were not what they seem to be[20]. The demand for non-regular workers' housing investment grows mainly because the housing price decreased. After shock, the non-regular workers who provide shorter worked hours than regular workers play a more important role in producing housing, the power of housing production, and its price fall (see the middle right in Figure 7). However, interestingly, the fall in price can be reinterpreted as follows. Declining housing prices stimulate non-regular workers' housing demand and prevent aggregate housing demand from falling more than necessary.

Although each response is not compatible because the size of shock in the empirical model is not the same as that of the theoretical model, to compare the differences in the empirical responses of both housing and aggregate consumption with the differences in the theoretical responses is insightful. In an empirical model, the degree of the response in housing is 6.25 times as great as that of aggregate consumption. Housing is 6.93 times as great, in terms of consumption, in the theoretical model. The results are not particularly different. Consequently, in the part of this paper describing calibration, it seems certain that the choices of values in deep parameters are consistent with those of the actual economy.

Saving and borrowing

The bottom right and left in Figure 7 display the responses of negative borrowing (i.e. saving) by regular workers to a ratio shock (left) and the response of positive borrowing (i.e. usual borrowing) by non-regular workers (right). Increasing in non-regular workers, regular workers reduce saving[21]. They

[20] I will document the full details later.

[21] When 'saving' is expressed as a kind of 'borrowing,' the steady state of saving is expressed as a negative sign. Therefore, what the positive response in this figure show

decrease it from the steady state by more than 6% and remain around 2%, even at 20 quarters. It is sure to be persistent. After the shock, non-regular workers change borrowing to a low level by more than 5%. Furthermore, they maintain such a low level. From 10 quarters, the response becomes positive. These results can be interpreted as follows. The increase in non-regular workers is simply equivalent to the decline in regular workers' income here. Therefore, if it occurs, then they reduce saving. Furthermore, non-regular workers are temporarily able to attain self-finance for purchasing housing without borrowing because of the fall in housing prices, and it is mostly during 10 quarters. Thereafter, when housing prices revert to the steady state and nominal interest rates fall, they recommence borrowing using housing as collateral.

4.3.2 Each response in between non-regular and regular

The immediately preceding subsection presented an exploration of the effects of an increasing ratio shock on some basic variables representing the economy. This subsection presents an examination of the reaction of each type of worker (non-regular worker or regular worker) to the shock. Although the demands of consumption and housing by non-regular workers and regular workers have been described, they are reviewed below.

After a shock, the demand for aggregate consumption declines. Non-regular workers add to consumption and regular workers decline. Therefore, because of the increase in non-regular workers who are part-time workers, output for consumption goods declines less than demand. A positive output gap occurs, and inflation increases slightly. According to total housing demand or each demand, the results are similar to those in the case of consumption goods. Non-regular workers need not turn to borrowing to purchase housing because they earn constant income irrespective of the shock and housing price fall. Regular workers, who have declining income, decide to decrease borrowing (see Figures 6-8).

Some discussion of the responses of income for each worker should be made. In the model, results of both all worked hours and every wage are displayed in Figure 9. Based upon the assumption of model, an increase in the ratio of non-regular workers means that the income of non-regular workers

is that saving is lower than the steady state level.

grows up. However, reading the figure, it can be readily understood that to generate such a mechanism is not easy. Although income for regular workers declines[22], income for non-regular workers mostly remains unchanged. In the labor markets of both consumption goods and housing, the decline in worked hours offsets the rise in wages.

Moreover, as the figure shows, the changes in labor demand and supply have results related to the impulse responses. First, the responses of worked hours and wage in labor market of consumption goods for regular workers are that worked hours decline by 0.02% and that wages also decline by 0.84%. Figure 5-(i) explains these results. In raising the ratio, the demand of labor force to regular workers declines: this indicates a leftward shift of curve. Furthermore, then, regular workers emphasize working rather than consumption and supply more worked hours (a rightward shift). Second, the responses of worked hours and wages in the labor market of housing for regular workers are that worked hours rise by 0.06% and that the wage decreases by around 0.79%. Some shifts in Figure 5-(ii) occur for mostly the same reasons as the case of consumption goods. Finally, the responses of worked hours and wage in labor market of consumption goods and housing for regular workers are that worked hours decline by 13.0% and 26.9% and that wages rise by 12.7% and 26.6%. Because housing declines completely, despite the emphasis on non-regular workers, they reduce their worked hours (a leftward shift) (see Figure 5-(iii)). Firms of both consumption goods and housing need not change demand for non-regular workers so that they attain minimum cost.

4.3.3 Comparison of responses in different parameter value

I have examined the responses of model variables under the baseline settings. In this subsection, in changing some parameter values, I gain new implications of the model.

The chosen parameters are s^*, m, and ρ_s. Let me think the reasons why they are picked up respectively. First, s^* means the steady-state ratio of non-regular workers to all workers. To revalue this parameter is equal to a change into non-regular workers in the economy. I allow the new values of s^* to be 0.17 and 0.51. The reason why more than 0.51 is not consider is that

[22]In the labor market related to housing, because the increasing rate of worked hours is greater the decreasing rate of wage, income is lowered.

it is not feasible that non-regular workers account for more than 50% of the whole workers in real economy. Second, m is the parameter that reflects how non-regular workers' borrowing is close to their housing value. The higher m is, the closer their borrowing is to the maximum limits. On the other hand, if m is low, borrowing is small even though housing is valued highly. Here m is assumed to be 0.30 and 0.80. Finally, the parameter ρ_s sets the persistence in the law of motion of the ratio shock. The model variable has been defined as the exogenous variable. Therefore, if the definition of s_t can be loosened, high persistence is interpreted to be a situation that non-regular workers have been hired for a longer time since they increased by more than steady state. So when I set ρ_s for 0.30 and 0.50 respectively, this means that non-regular workers their employment is not so long.

Figure 10 through 15 illustrate how model variables respond to the ratio shock under alternative values of the three chosen parameters. First of all, for s^*, Figure 10 and 11 display the natural and clear result. That is, the less non-regular workers are, the better of course. The figures of both demand and supply of every goods particularly illustrate that the smaller the steady state ratio of non-regular workers is, the smaller the negative deviations are. Next, let me see the results of m (see Figure 12 and 13). Iacoviello (2005) stressed that the higher the value of loan-to-value is, the more non-regular workers consume in the reaction to asset price rising. Therefore, generally speaking, m has a function that amplifies some effects on consumption (Iacoviello's "the asset price"). Although the sign is opposite to Iacoviello, the same results are not found in this paper. The bigger the value of loan-to-value is, the less consumption decline by the negative effect of the ratio shock (and the negative response of asset price). Hence, as the results shown, it turned out that the parameter m that is expected to play a role to increase borrowing and to expand consumption contrarily amplifies the negativeness of consumption. Finally, in Figure 14 and 15, when the persistence of shock process is low, the convergence is naturally rapid or the change to the shock is small. I can conduct an implication as follows. In order to avoid the negative deviation from the steady state, the added non-regular workers should be not employed for so long time.

The responses of model variables under the baseline settings were examined. This subsection, in changing some parameter values, presents some novel implications of the model.

The chosen parameters, selected for various reasons, are s^*, m, and ρ_s. First, s^* represents the steady-state ratio of non-regular workers to all workers. To revalue this parameter is equivalent to a change in non-regular workers in the economy. The new values of s^* are set as 0.17 and 0.51. Values greater than 0.51 are not considered because it is not feasible that non-regular workers account for more than 50% of all workers in a real economy. Second, m is the parameter reflecting how non-regular workers' borrowing is close to their housing value. The higher m is, the closer their borrowing is to the maximum limits. However, if m is low, then borrowing is small even though housing is valued highly. Here m is assumed to be 0.30 and 0.80. Finally, parameter ρ_s sets the persistence in the law of motion of the ratio shock. The model variable has been defined as the exogenous variable. Therefore, if the definition of s^* can be loosened, high persistence is interpreted to be a situation by which non-regular workers have been hired for a longer time because they increased by more than steady state. Therefore, ρ_s was set for 0.30 and 0.50 respectively, non-regular workers have a shorter term of employment.

Figures 10 through 15 portray how model variables respond to the ratio shock under alternative values of the three chosen parameters. First, for s^*, Figures 10 and 11 display the natural and clear result: the fewer the non-regular workers are, the better. The figures of both demand and supply of every good particularly illustrate that the smaller the steady state ratio of non-regular workers is, the smaller the negative deviations are. Next, the results of m (see Figures 12 and 13) are noteworthy. Iacoviello (2005) emphasized that the higher the value of loan-to-value is, the more non-regular workers consume in the reaction to asset price rising. Therefore, generally speaking, m amplifies some effects of consumption (Iacoviello's "asset price"). Although the sign is opposite to that presented by Iacoviello, the same results are not found from results of this study. The larger the value of the loan-to-value is, the less consumption declines because of the negative effect of the ratio shock (and the negative response of asset price). Therefore, as results show, parameter m, which is expected to play a role to increase borrowing and to expand consumption, contrarily amplifies the negativeness of consumption. Finally, in Figures 14 and 15, when the persistence of shock process is low, the convergence is naturally rapid or the change to the shock is small. The salient implications are as follows. To avoid the negative deviation from the steady state, the added non-regular workers should be not contracted for employment for long periods.

4.4 Conclusions

This paper has explained that an increase in non-regular workers can account for the current stagnated demand in Japan. Use of a dynamic stochastic general equilibrium (DSGE) model yields some policy implications. The key idea is that, by raising the number of non-regular workers who face borrowing constraints, expenditures on goods that require external finance such as housing investment decline, which causes stagnated demand in Japan.

By the increase of non-regular workers, results show that expenditures on consumption and housing decrease, and that housing is more sensitive to a non-regular workers' shock than consumption is. These results support the empirically obtained results. As featured results coming from the model, although income for regular workers declined, against expectations, the non-regular workers' income was constant. Under such circumstances, increasing housing demand of non-regular workers results from a fall in housing prices.

The model presents three implications as follows: 1) it is better to lower the number of non-regular workers; 2) even though it is easier to borrow, spending does not increase; and 3) even if non-regular workers are employed, they should not be employed over the long term.

One limitation of the model is that, for simplicity, the ratio of non-regular workers was examined as an exogenous variable. In fact, the variable should be controlled as a problem of firm optimization.

Table 4.1: Baseline Parameter Value

Parameters	Descriptions	Value	Reference
Regular worker			
β_R	discount factor	0.996	Original
η_R	labor supply aversion	3.000	Sugo and Ueda (2008)
e_R	labor supply aversion	0.800	Sugo and Ueda (2008)
Non-regular worker			
β_N	discount factor	0.950	Original
η_N	labor supply aversion	2.000	Sugo and Ueda (2008)
e_N	housing depreciation	0.400	Original
m	loan-to-value	0.500	Original
Entrepreneurs & Retailers			
μ_c	income share	0.630	Original
μ_h	income share	0.700	Original
θ	probability fixed price	0.875	Sugo and Ueda (2008)
α	elasticity of substitution	30.00	Sugo and Ueda (2008)
Economy			
f_c	consumption habit	0.110	Original
f_h	housing habit	0.000	Original
j	weight on housing services	0.100	Iacoviello (2005)
δ_h	housing depreciation	0.010	Original
Monetary Policy & Shocks			
γ_R	lagged interest rate	0.842	Sugo and Ueda (2008)
γ_π	inflation	0.606	Sugo and Ueda (2008)
γ_x	output gap	0.110	Sugo and Ueda (2008)
ρ_A	productivity	0.949	Sugo and Ueda (2008)
ρ_s	non-regular worker ratio	0.900	Original
σ_A	productivity	0.843	Sugo and Ueda (2008)
σ_s	non-regular worker ratio	0.100	Original
σ_R	monetary policy	0.066	Sugo and Ueda (2008)

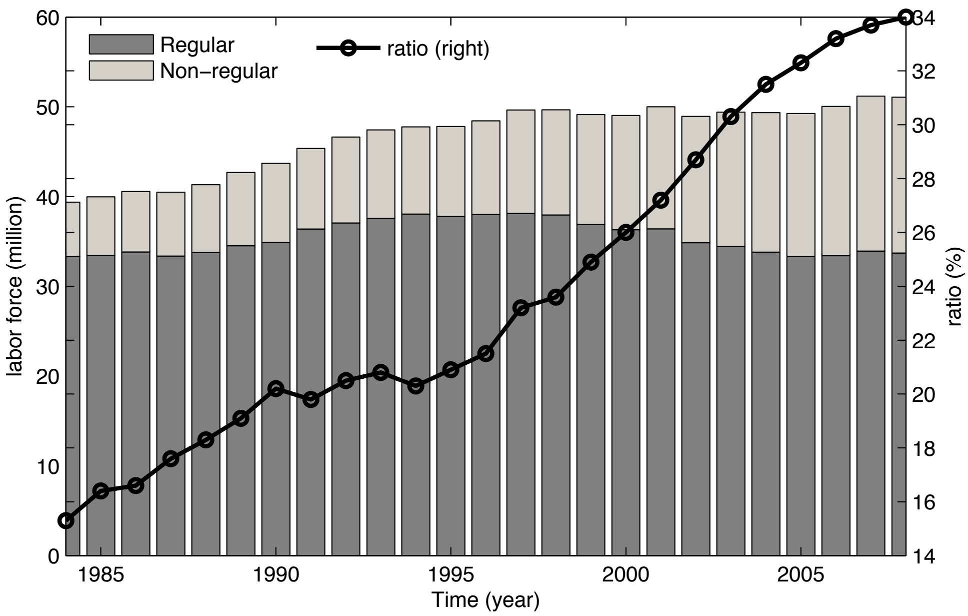


Figure 4.1: Employee by type of employment and non-regular worker ratio, Japan

Source: Special Survey of the Labour Force Survey, from 1984 to 2008.
Note: Bar graph shows the number of employees by type of employment. The unit is millions. The charcoal bar denotes regular workers, and the light gray denotes non-regular workers. The line graph shows the fraction of non-regular workers, for which the unit is percentage on the right axis. Non-regular workers include part-time workers, temporary workers, dispatched workers from temporary labor agency, contract employees or entrusted employees, and others. The regular workers are regular staff or employees.

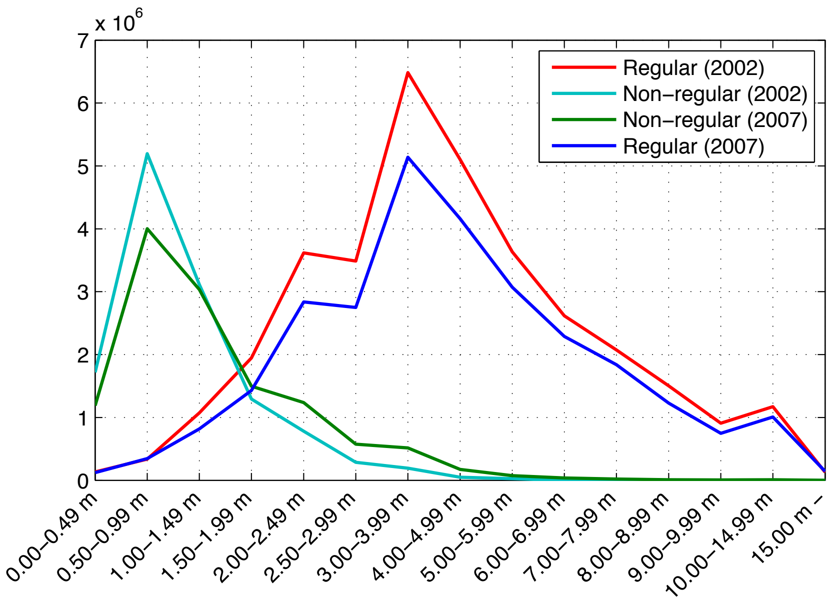


Figure 4.2: Distribution of Annual Income, Japan

Source: Employment Status Survey, 2002 and 2007.
Note: The definition of non-regular workers is the same as that in Figure 1. The vertical axis expresses the number of employees. The unit is millions. The horizontal axis shows the class of annual income earned by the employees. The unit is millions of yen. The medians are roughly estimated as around 0.8 million (Non-regular) and around 3.9 million (Regular) in 2002, and to be around 1.2 million (Non-regular) and around 4.1 million (Regular) in 2007.

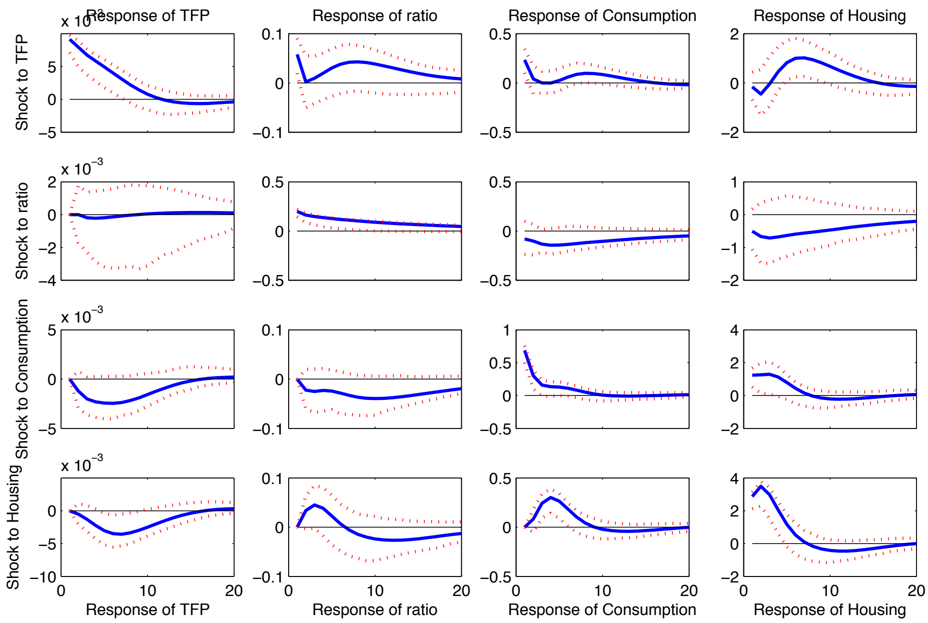


Figure 4.3: VAR Evidence, Japan

Note: VAR estimated from 1990Q4 to 2008Q4. The dashed lines indicate 90-percent confidence bands. The Choleski ordering of the impulse responses is TFP, $ratio$, $Consumption$, $Housing$. Coordinate: percent deviation from the baseline. TFP is calculated based upon Kamada and Masuda (2001) and Kawamoto (2004), who adopted the *TANKAN DI*.

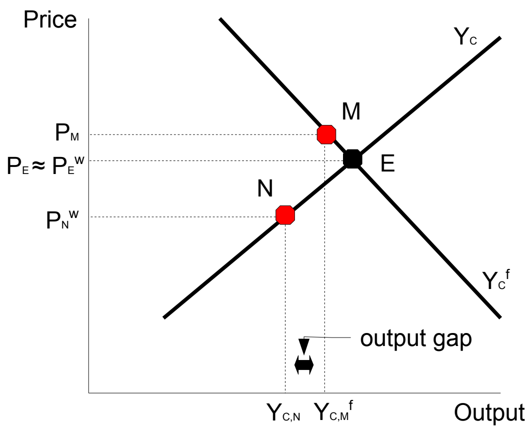


Figure 4.4: Diagram of the relation between the entrepreneurs' production function Y_c and the retailers' demand function Y_c^f.

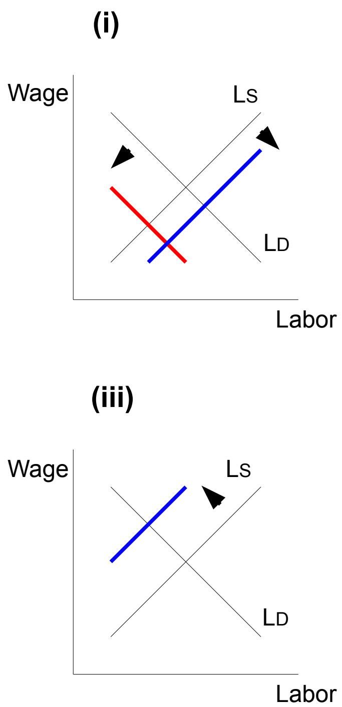


Figure 4.5: Diagram of the relation between the labor supply and labor demand: (i) shows the regular workers market for consumption goods; (ii) shows the regular worker market for housing investment; and (iii) shows the non-regular worker market for consumption goods and housing investment.

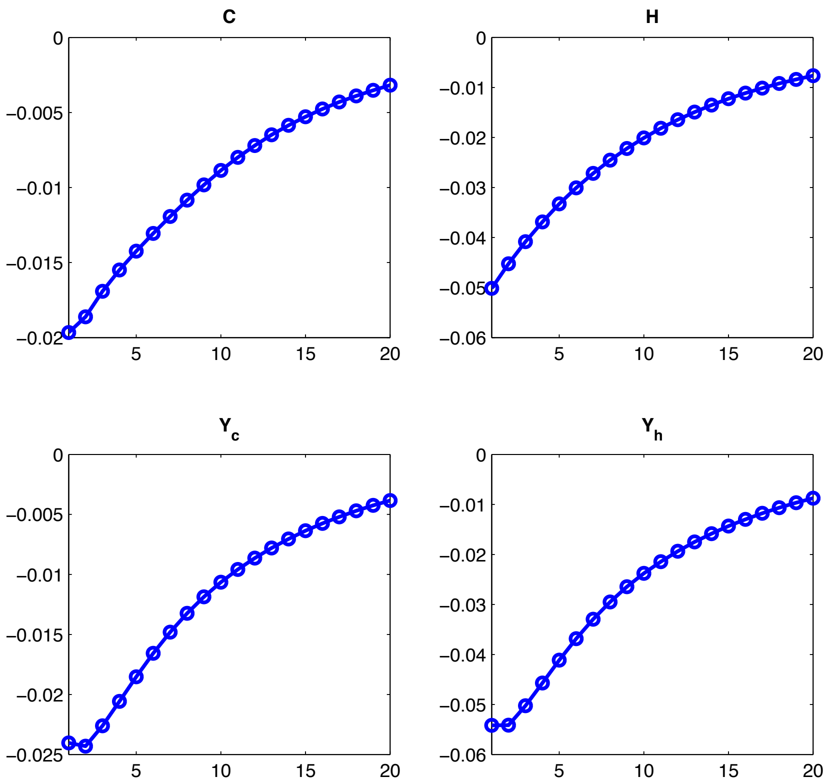


Figure 4.6: Impulse responses to a increasing ratio shock.
Note: Vertical axis: deviation from steady state. Horizontal axis: time horizon in quarters.

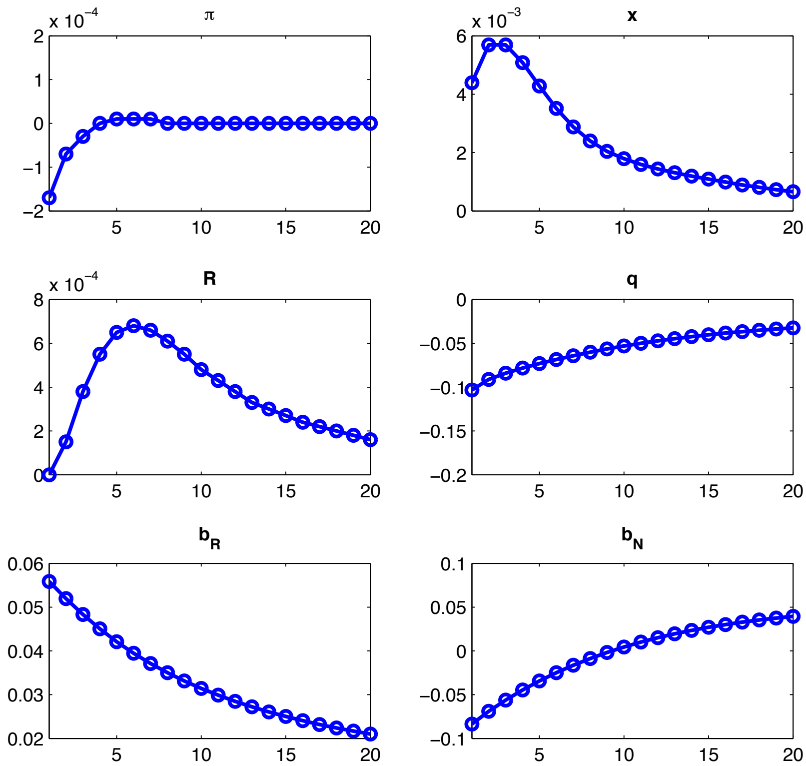


Figure 4.7: Impulse responses to a increasing ratio shock.
Note: Vertical axis: deviation from steady state. Horizontal axis: time horizon in quarters.

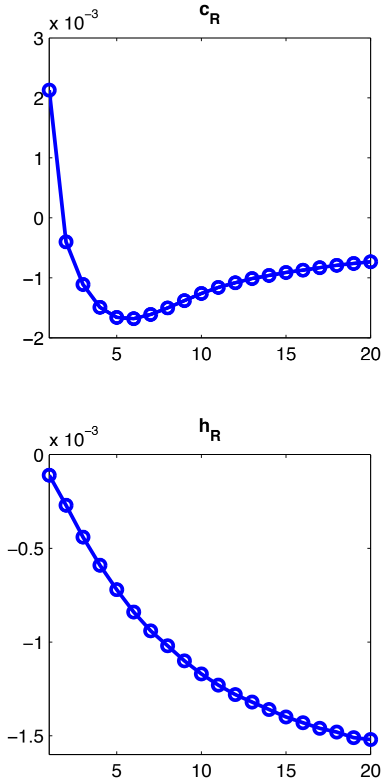


Figure 4.8: Impulse responses to a increasing ratio shock.
Note: Vertical axis: deviation from steady state. Horizontal axis: time horizon in quarters.

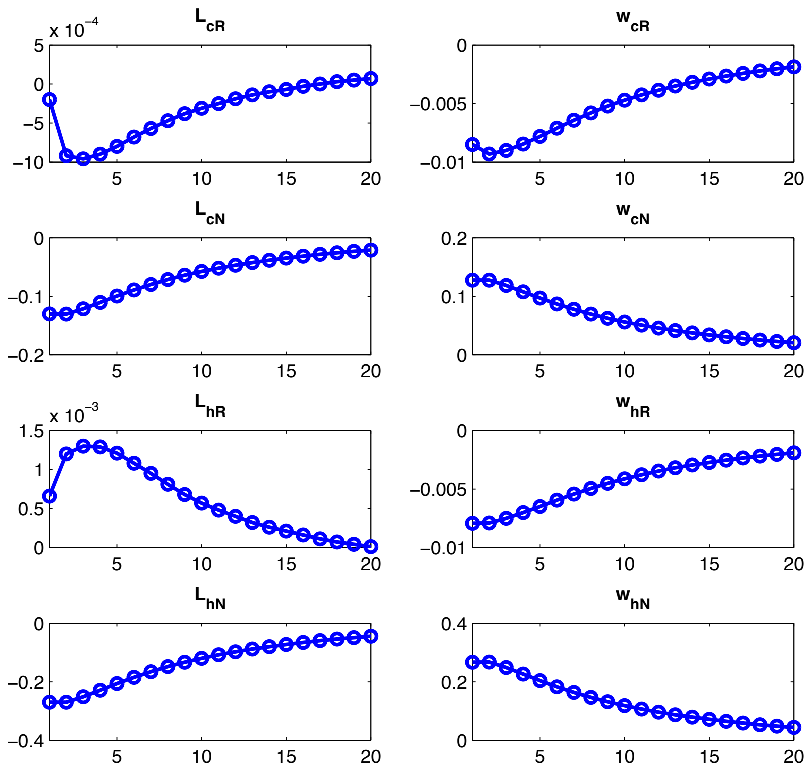


Figure 4.9: Impulse responses to a increasing ratio shock.
Note: Vertical axis: deviation from steady state. Horizontal axis: time horizon in quarters.

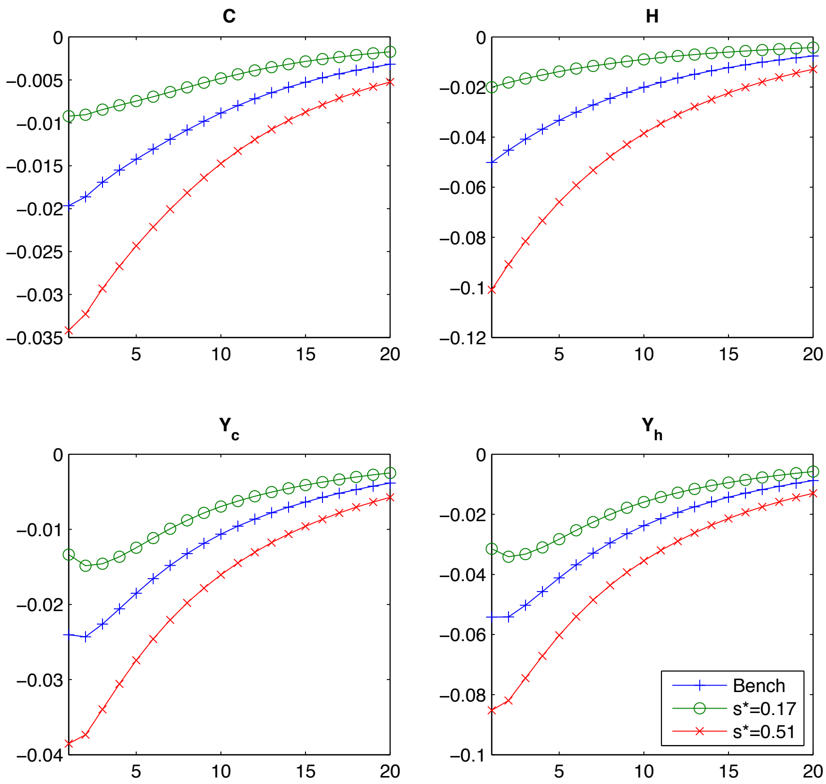


Figure 4.10: Impulse responses to a increasing ratio shock: effect of varying the steady state of ratio.
Note: Vertical axis: deviation from steady state. Horizontal axis: time horizon in quarters.

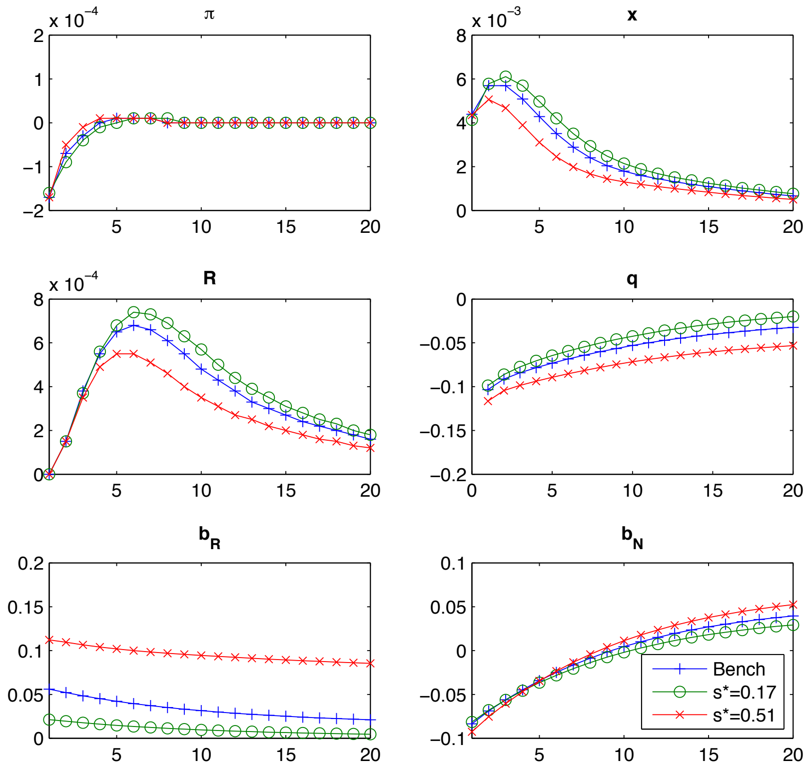


Figure 4.11: Impulse responses to a increasing ratio shock: effect of varying the steady state of ratio.
Note: Vertical axis: deviation from steady state. Horizontal axis: time horizon in quarters.

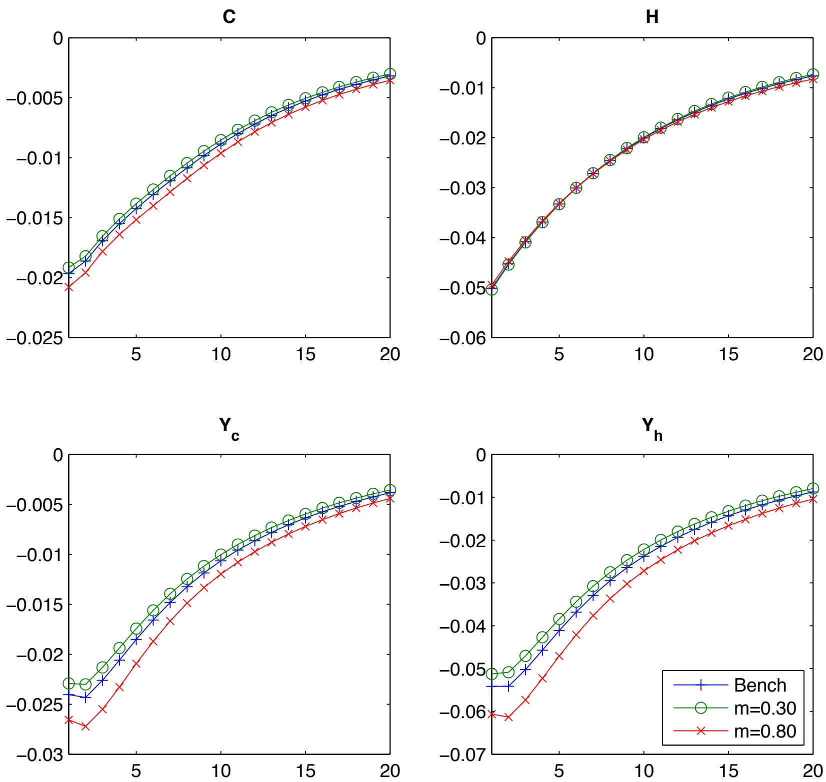


Figure 4.12: Impulse responses to a increasing ratio shock: effect of varying 'loan-to-value'.
Note: Vertical axis: deviation from steady state. Horizontal axis: time horizon in quarters.

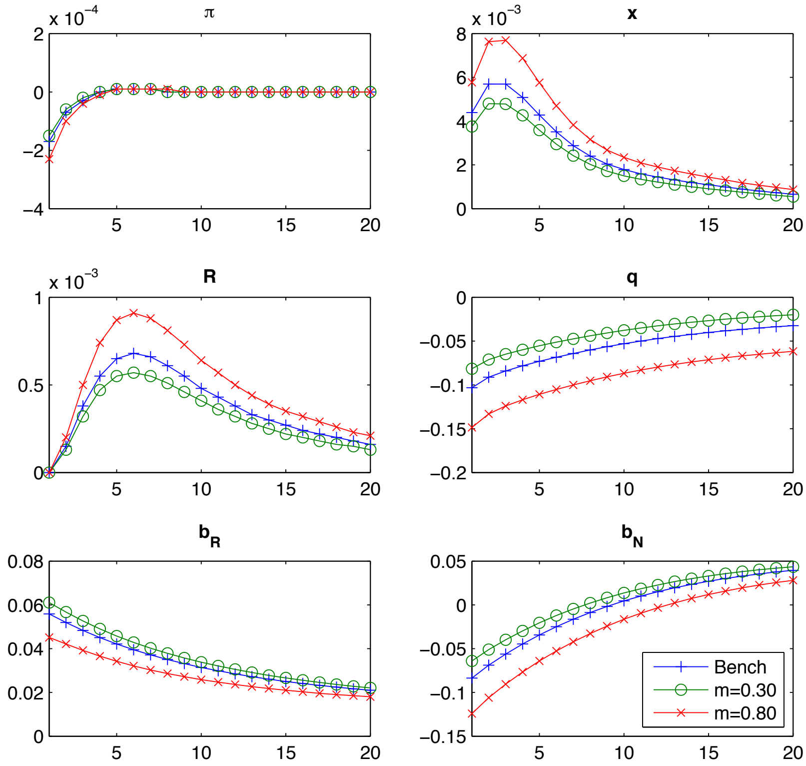


Figure 4.13: Impulse responses to a increasing ratio shock: effect of varying 'loan-to-value'.
Note: Vertical axis: deviation from steady state. Horizontal axis: time horizon in quarters.

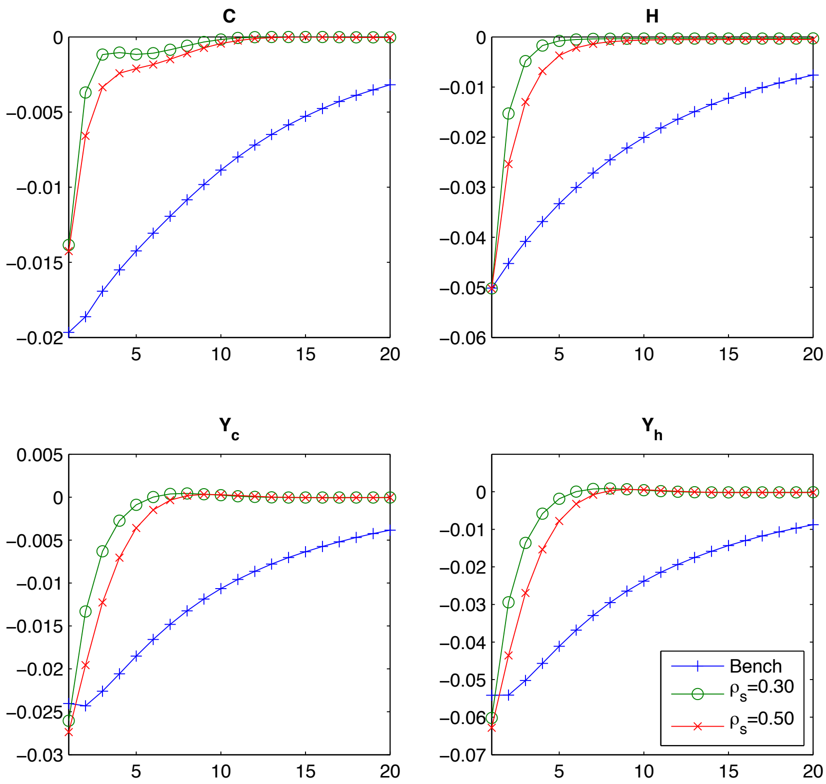


Figure 4.14: Impulse responses to a increasing ratio shock: effect of varying the degree of persistence.
Note: Vertical axis: deviation from steady state. Horizontal axis: time horizon in quarters.

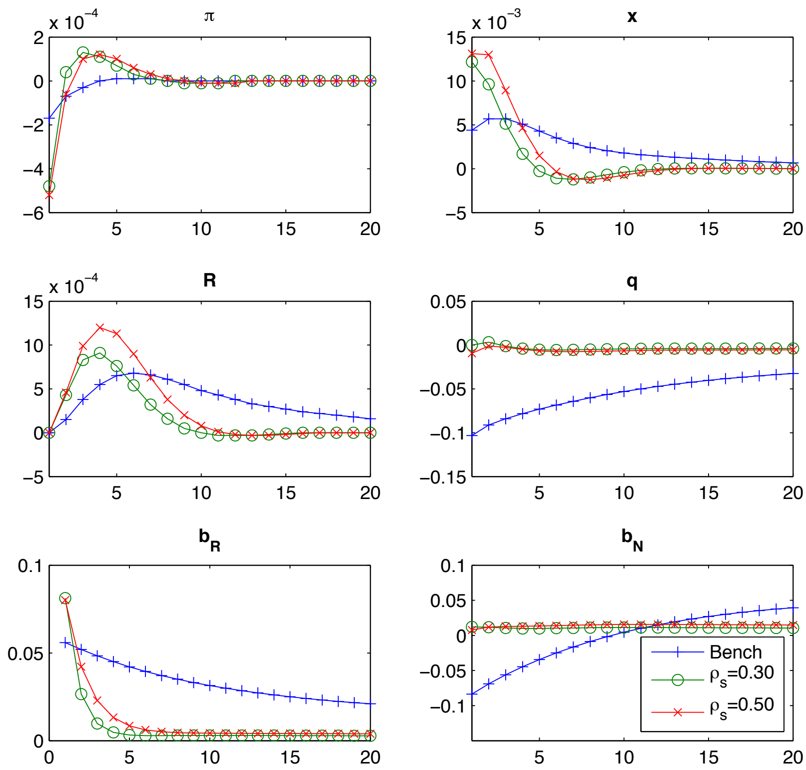


Figure 4.15: Impulse responses to a increasing ratio shock: effect of varying the degree of persistence.
Note: Vertical axis: deviation from steady state. Horizontal axis: time horizon in quarters.

Chapter 5

Conclusions

In Chapter 2, this study demonstrates quantitatively the degree to which uncertainty originates from the revision of data inherent in the real-time estimation of the Japan's equilibrium real interest rate (ERR). It also presents attempts to reduce that uncertainty. Results show that markedly high uncertainty results from data revision. A modified model is proposed to estimate a more credible ERR that includes lowered uncertainty with revision-free data. Furthermore, the Bank of Japan, while facing that uncertainty has made three judgment errors because it did not recognize reliable ERR.

In Chapter 3, this study reconsiders whether the monetary policy in the late 1980's was delayed. There is not any previous studies that evaluate the past monetary policy using the model-consitent latent variable from Bayesian estimation. I find that there does not exist the delay of monetary policy.This paper presents reconsideration of whether monetary policy in the late 1980s was delayed. No report in the literature describes studies evaluating past monetary policy using the model-consistent latent variable from Bayesian estimation. The delay of monetary policy can be found exactly. This paper confirms the necessity of the zero lower bound constraint in a DSGE model.

In Chapter 4, this study specifically examines features of labor supply heterogeneity in Japanese households and describes how such a structure affects household expenditure, which has stagnated during the last two decades. The particular circumstances represent the increase of non-regular workers but are not necessarily limited to Japan. Non-regular workers are definable in many dimensions, but a common feature is that they have quite unstable contracts of employment. If such labor increases greatly, then one can assess the impact on the actual economy. Therefore, a general equilibrium model was constructed to explain some empirical VAR evidence. The model shows that the reactions of aggregate consumption and housing investment to the shock of increasing non-regular worker ratio are negative and that they are consistent with empirical results. Housing investment exhibits greater sensitivity to the shock. Moreover, decreasing output for consumption goods and housing investment in response to the shock is greater than that decrease of demand. This paper suggests that employing few non-regular workers is preferred and that non-regular workers should not be employed for long periods.

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