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Abstract

In this paper I investigate the effects of changes in demand structure caused by population aging on the Japanese economy using a multi-sector new Keynesian model with job creation/destruction. I consider upward revisions in forecast for the speed of Japanese population aging as unexpected shocks to its demand structure. I find that the shocks caused around 0.3 percent point deflationary pressure on year-to-year inflation, 0.3 to 0.4 percent point increase in unemployment rates, and 1.8 percent point decrease in real GDP from the early 1990s to the 2000s in Japan. I also find that the repetition of such upward revisions made those effects look more persistent.

Keywords: Population Aging; Matching; Productivity; Deflation
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1 Introduction

Population aging affects macroeconomic performance mainly through the supply side of the economy. For example, as the ratio of working population to total population decreases due to population aging, the growth rate of GDP per capita slows down unless labor productivity improves and offsets the decrease in labor input.[1] Also, from the fiscal viewpoint, since population aging results in a decrease in tax base and an increase in government expenditure mainly through an increase in social security costs, economic activity may slow down due to the burden of the fiscal costs caused by population aging.

In this paper I investigate the economic consequences of population aging in Japan, where population aging is proceeding much faster than in other developed countries. A distinguished difference from previous studies is that I focus on the effects of population aging on changes in the demand side of the economy rather than on its supply side.[2] That is, I focus on the fact that population aging results in changes in the demand structure of the economy, reflecting variation in consumption pattern across age groups. For example, since young people tend to buy more durable goods such as cars and electric appliances while old people tend to use more money for service expenditure such as medical care and traveling, population aging implies an increase in demand for the service sector compared with that for the manufacturing sector.

Another difference from the previous studies is that I interpret the repeated revisions in the official forecast for Japanese population aging as unexpected shocks to the economy. Figure 1 shows the forecasts for the ratio of the population over 60 years old to the population

[1]Since a decrease in labor input means an increase in capital per labor, labor productivity is likely to increase through a growth in capital deepening. However, considering the recent increase in life expectancy in developed countries, the improvement in labor productivity is not enough to offset the effect of the decrease in labor input on GDP per capita.

[2]Some empirical studies investigate the effect of population aging on the demand side of the economy whereas the number of such studies is much more limited compared with studies about the effect on the supply side of the economy. Borsch-Supan (2003) argues that changes in age structure result in changes in the demand structure using German data. He mentions the possibility that such changes in the demand structure may induce an increase in unemployment, particularly if there are labor market frictions, because they trigger changes in employment pattern across industries. Fougere et al. (2007) construct an overlapping generation model with multiple industries and show that population aging results in significant changes in demand structure in Canada. Luhrmann (2008) investigates the effect of population aging on UK consumer demand structure. She concludes that changes in age structure in the UK have substantial effects on its consumer demand structure along with income redistribution towards the older age group. Rausch (2009) shows that population aging induces substantial changes in demand structure by using a overlapping generation model and German data.

over 20 years old in Japan.[3] It shows that the forecast is revised upward every time they make a new forecast, implying that people have recognized the progress of population aging gradually. As households and firms make their decisions based on the forecasts for population aging in a forward-looking manner, such revisions are reflected in their behavior when the new forecasts are announced. I investigate the effects of the repeated upward revisions in the forecasts for the speed of Japanese population aging by considering them as unexpected shocks to the economy.

I establish a model containing the following two channels through which the changes in demand structure affect aggregate variables such as output and inflation. The first channel is an increase in structural unemployment rates. As the demand structure of the economy changes, a shift in labor force between industries should occur to meet the demand shift, but due to various labor market frictions, structural unemployment rates are likely to increase during the shift. Figure 2 shows the development of Japanese structural unemployment rates in the last thirty years. The figure indicates that they increased in the 1990s and have remained at a high level after the increase, which is consistent with the correlation between population aging and structural unemployment rates described above. In this paper, I quantify the response of structural unemployment rates to a change in demand structure using a multi-sector model with job creation/destruction. I assume that each industry has its own matching function in the spirit of the Mortensen-Pissarides model and estimated it using Japanese data.

The second channel that I highlight in this paper is the change in aggregate productivity arising from the resource (re)allocation across industries. In particular, I focus on the fact that population aging is likely to result in a demand shift from the manufacturing sector products towards those of the non-manufacturing sector. In the meantime, the productivity of the non-manufacturing sector has been allegedly lower than that of the manufacturing one in Japan. Figure 3 shows productivity and labor input in the Japanese economy over the last two decades. The figure indicates that the productivity increases in the manufacturing sector while labor input decreases in the manufacturing sector in comparison with the non-manufacturing sector. These facts regarding cross-sector productivity and labor input would imply that Japan's aggregate productivity has been undermined because the lower (higher) productivity sector has expanded (diminished) in terms of labor input, possibly reflecting the shifts in demand structure that have been taking place in line with population aging.[4]

[3]The forecasts are constructed by National Institute of Population and Social Security Research based on the latest national census at that time. The data is available at `http://www.ipss.go.jp/index-e.asp`.

[4]This fact is compatible with alternative interpretation. For examples, Ngai and Pissarides (2008) and Shioji (2010) show that when the elasticity of substitution between two types of goods is lower than one,

In addition to the effects on real economic activities, I also investigate the outcomes of inflation in response to the changes in the demand structure along with population aging.[5] Notably, Japan's economy has been faced with long-lasting deflationary pressure since the 1990s. Against the backdrop, I run into the research question of whether population aging contributes to the deflation. To this end, I incorporated nominal rigidities in the model, assuming that firms in each industry face a monopolistically competitive market and price adjustment costs as typically formulated in standard new Keynesian models. With the framework ready for use, I investigate changes in general and relative prices through a new Keynesian Phillips-curve in each sector.[6]

For the quantitative assessment, I calibrate the model with Japanese data and calculate a transition path based on the official forecasts published by the National Institute of Population and Social Security Research for population aging in Japan. I find that the aforementioned faster-than-expected population aging has had the following effects over the two decades from the early 1990s. First, structural unemployment rates continue to remain at 0.3 to 0.4 percent point higher than those in the early 1990s and will continue to persist until the 2020s. Then, presuming that no further similar shocks hit the economy, aggregate employment will over time recover somewhat but the demand shift would leave a permanent scarring effect on employment with the structural unemployment rate being raised by 0.2 percent point compared to the period prior to the shock. Second, reflecting the increase in unemployment rates and the decline in aggregate productivity, Japan's real GDP gradually wanes to a 1.8 percent point lower level than that of the early 1990s. Third, the simulation results indicate that inflation rates have been subject to, approximately, 0.2 to 0.3 percent deflationary pressures in terms of year-to-year inflation rate over the past two decades. The results reaffirm that the repetition of the upward revisions brought about the protracted deflationary pressure during the same period.

The rest of the paper is organized as follows. In Section 2, I describe the model structure and characterize the equilibrium of the economy. In Section 3, I calibrate the model and discuss how the observed changes in the forecast for population aging can be translated as

it is optimal to allocate more labor input to the industry with *lower productivity growth* rather than the industry with *higher productivity growth*.

[5]Lindh and Malmberg (1998, 2000) investigate the relationship between age structure and inflation, and find that decreases in the population of middle-aged people induce inflation. They argue that their finding is consistent with the hypothesis that decreases in net savers create excess demand for investment and generate inflation, but they also argue that it is compatible with other theoretical explanations.

[6]In terms of the structure of model, this paper is related to the following two literatures: new Keynesian models with multiple sectors (e.g., Aoki (2001) and Barsky et al. (2007)) and new Keynesian models with labor market frictions (e.g., Gertler et al. (2008) and Hirata (2012)).

the sequence of unanticipated shocks in the model. Section 4 gives the simulation results, while some concluding remarks are given in Section 5.

2 Model

The economy consists of four types of agents: households, employment agencies, firms, and monetary authority. There are three industries ($k = 1, 2$ and 3) producing different consumption goods. The household consumes a consumption basket that consists of the three consumption goods and supplies a labor force. The employment agency intermediates between the household's labor supply and the firm's labor demand in exchange for some fees. The model is a type of a decentralized version of Phelan and Trejos (2000) except that there is a continuum of firms facing a monopolistically competitive consumption goods market and price adjustment costs.

2.1 Household

I assume a representative household. It maximizes its lifetime utility by a consumption basket and labor supply. The consumption basket, c, consists of three goods, c_1, c_2, and c_3, which are not perfectly substitutable with each other,

$$c = \left[\sum_{k=1}^{3} \alpha_k^{1-\rho} c_k^{\rho}\right]^{1/\rho} \tag{1}$$

where ρ is a parameter for elasticity of substitution between the three goods. α_k is a weight of each consumer product in the consumption basket and satisfies $\alpha_1 + \alpha_2 + \alpha_3 = 1$. In a quantitative analysis part of this paper, the weight of each product is assumed to have changed over time according to population aging.

The budget constraint for the household is as follows:

$$pc + \frac{b'}{R} = b + p\left[\sum_{k=1}^{3} w_k n_k h_k - \sum_{k=1}^{3} g_k n_k\right]. \tag{2}$$

where b is a one-period nominal bond. A nominal interest rate, R, which is applied to the one-period nominal bond, is determined by the monetary authority according to a monetary policy rule. The price of the consumption basket, p, is defined by the following equation,

$$pc = \sum_{k=1}^{3} p_k c_k. \tag{3}$$

The price of the consumption basket is considered as a general price such as CPI in this model.

The household changes its labor supply by adjusting both an extensive and an intensive margin. That is, it chooses both the number of employees, n_k, and hours worked, h_k, in each industry in every period. The household's total wage income is denoted by $\sum_k w_k n_k h_k$ where w_k are real wages per hour. The household is assumed to pay a maintenance fee, g_k, to the employment agency in order to keep its employment status. Since the maintenance fee is proportional to the number of employees, the total maintenance fee is $\sum_k g_k n_k$.

The household optimization problem in recursive formulation is now defined as follows:

$$V_h(b) = \max_{b', h_k, n_k} \left[\log(c) - \sum_{k=1}^{3} \psi n_k h_k^{1+\mu} + \beta V_h(b') \right] \tag{4}$$

subject to (1), (2), and (3). β is a subjective discounting factor. Note that while the labor disutility is convex with respect to hours worked in each sector, it is linear with respect to the number of employees in each sector. Therefore, there is a trade-off between the convex disutility for increasing hours worked and the additional fee to be paid to the employment agency for increasing the number of employees.

2.2 Employment Agency

The employment agency intermediates between the household's labor supply and the firm's labor demand in each sector. Every household must use the employment agency in order to obtain a job opportunity. When the employment agency succeeds in matching the labor supply and demand, the household has to pay a maintenance fee to the employment agency to keep its employment status.

The number of matches in sector k is denoted by N_k. Note that the number of matches in sector k is equal to the number of employees working in sector k by definition. The number of matches is assumed to be determined according to the following law of motion,

$$N'_k = (1 - \delta) N_k + N_k s_k m_k^{\phi} u^{1-\phi} \tag{5}$$

where δ is a job destruction rate, implying that a fraction of $(1 - \delta)$ of employees remain employed in the same sector in the next period. The number of new matches (i.e., the number of new hires) are determined by a matching function for each industry, $s_k m_k^{\phi} u^{1-\phi}$, in the same spirit as the Motensen-Pissarides model.[7] m_k is hours worked of employment

[7] Petrongolo and Pissarides (2001) give an excellent survey on theoretical and empirical studies about a matching function in labor markets. Ohta et al. (2008) review empirical studies about the Japanese labor market situation including the matching efficiency from the 1990s to the 2000s.

agency's employees *per match* in sector k. That is, m_k is hours worked that they used for realizing one match in sector k. This labor input by the employment agency represents a cost to match the labor supply and demand in sector k. u represents unemployment rates in the economy, which is defined as

$$u = 1 - \sum_k N_k. \tag{6}$$

Note that the working population in the economy is normalized to one. s_k is matching efficiency in sector k. In summary, the matching function says that the number of new matches would increase at the same rate of the matching efficiency when staff at the employment agency works more for realization of new matches and/or unemployment rate rises.

The employment agency optimization problem in recursive formulation is defined as follows:

$$V_e(N_1, N_2, N_3) = \max_{m_k, N'_k} \left[\sum_k g_k N_k - \sum_k w_k N_k m_k + \Lambda V_e(N'_1, N'_2, N'_3) \right] \tag{7}$$

subject to (5) and (6). g_k is the maintenance fee paid by the household. Since it is the only source of the employment agency's revenue, its total revenue is $\sum_{k=1}^{3} g_k N_k$. In order to match the labor supply and demand, the employment agency needs to hire its employees at the same wage rate in sector k, w_k. As m_k is hours worked of employment agency's employees per match in sector k, the total labor cost is $\sum_k w_k N_k m_k$. Since the employment agency is assumed to be owned by the household, its next period's value function is discounted by a stochastic discount factor of the household,

$$\Lambda \equiv \beta \frac{1/c'}{1/c}. \tag{8}$$

2.3 Firm

There is a continuum of firms in each sector k. The firm faces a monopolistically competitive goods market and price adjustment costs as in a standard new Keynesian model. The firm i in sector k maximizes its profit by choosing (1) total labor input, $H_{i,k}$, i.e., the number of employees times hours worked per employee and (2) the price of the consumption goods that the firm produces, $p_{i,k}$. The firm has the following linear technology,

$$y_{i,k} = a_k H_{i,k} \tag{9}$$

where $y_{k,i}$ are consumption goods and a_k is productivity. Note that productivity is assumed to be common among all firms in sector k.

There are also intermediate goods producers in each sector k. They buy each firm's product, $y_{i,k}$ at the price of $p_{i,k}$ and produce consumption goods in sector k, y_k, using the CES aggregator,

$$y_k = \left[\int_0^1 y_{i,k}^{\frac{\nu-1}{\nu}} di \right]^{\frac{\nu}{\nu-1}}. \tag{10}$$

Then they sell y_k to the household at the price of p_k. As a result of their profit maximization, the demand function for $y_{i,k}$ becomes

$$y_{k,i} = \left(\frac{p_{k,i}}{p_k} \right)^{-\nu} y_k. \tag{11}$$

The optimization problem for firm i in sector k in recursive formulation is defined as follows:

$$V_f(p_{k,i,-1}) = \max_{H_{k,i}, p_{k,i}} \left[\frac{p_{k,i}}{p_k} y_{k,i} - \frac{w_k}{p_k} H_{k,i} - \frac{\gamma}{2} \left(\frac{p_{k,i}}{p_{k,i,-1}} - \pi^* \right)^2 y_k + \Lambda V_f(p_{k,i}) \right] \tag{12}$$

subject to (9) and (11). $p_{k,i}/p_k$ and w_k/p_k are real prices of $y_{i,k}$ and real wages relative to p_k. It faces a quadratic price adjustment cost, $\gamma \left(p_{k,i}/p_{k,i,-1} - \pi^*\right)^2 y_k/2$ where $p_{k,i,-1}$ is the price of $y_{i,k}$ in the previous period and π^* is inflation rate in a steady state. Note that the firm is also assumed to be owned by the household, its next period's value function is discounted by Λ which is defined in (8). A new Keynesian Phillips-curve in each sector k is derived as the solution for the optimization problem for firm i in sector k.

2.4 Monetary Policy

I assume that the nominal interest rate, R, is set according to a Taylor-rule,

$$\frac{R}{R^*} = \left(\frac{\pi}{\pi^*} \right)^{d_\pi} (\tilde{y})^{d_y} \tag{13}$$

where π^* is a target inflation rate for the monetary authority and R^* is a steady state interest rate which is consistent with the target inflation rate. $\tilde{y}$ is an aggregate output gap.

2.5 Market Clearing Conditions

There are nine markets in the economy: the consumption goods market and the two labor markets (intensive and extensive margin) in three sectors. Market clearing conditions for these markets are as follows:

$$c_k = y_k \tag{14}$$

$$n_k = N_k \tag{15}$$

$$n_k h_k = H_k + N_k m_k \tag{16}$$

where the prices in these markets are p_k, g_k, and w_k. The first and second equations are straightforward. The third equation says that the household's total labor supply should be equal to sum of labor inputs for production and matching.

3 Quantitative Analysis

In this section, I investigate quantitative implications of the model. In particular, I focus on economic consequences of a change in demand structure caused by population aging. I categorize the three industries in the model as follows: Sector 1 (Sector 2) represents a industry producing consumption goods that old (young) people tend to prefer. Sector 3 denotes a industry producing consumption goods that are neutral to a consumer's age. As the weight of consumption goods produced in each industry in the consumption basket, α_k, determines the relative preferences between the three consumption goods, I interpret changes in α_k as exogenous changes in the demand structure of the economy. That is, α_k is not considered as a constant parameter but a time-variant variable, $\alpha_{k,t}$.[8] I calculate a future path of $\alpha_{k,t}$ consistent with Japanese demand structure by age group and Japanese population aging and insert it into a calibrated model. Given this exogenous path of $\alpha_{k,t}$, I compute a transition path of endogenous aggregate variables such as output, unemployment rates, and inflation. In addition, since the forecasts for Japanese population aging have been repeatedly revised upward, I interpret the repeated revisions as unexpected shocks to the future path of $\alpha_{k,t}$.

The outline of the simulation is as follows. First, I calibrate the model parameters using Japanese data. Second, I calculate a future path of α_k consistent with Japanese demand structure by age group and Japanese population aging. Third, I insert the exogenous path of α_k and calculate a deterministic transition path of the economy.

3.1 Calibration

I set one period in the model to a quarter. For the preference parameters, I set a subjective discount factor β to 0.99. I adopt a quadratic labor disutility, meaning $\mu = 1$. I choose a disutility parameter ψ so that the steady state hours worked is equal to one as a normalization. Since I do not have any evidence about elasticity of substitution between consumption goods in Japan, I set $\rho = -2$, implying that elasticity of substitution between consumption

[8] I can conduct the same quantitative analysis when I consider $\alpha_{k,t}$ as state variables rather than parameters.

goods is 0.33. This value is within the range for estimation values in other countries and a more conservative value than 0.11 in Phelan and Trejos (2000).

For the parameters for the firm, I set elasticity of substitution in a monopolistically competitive consumption goods market $\nu = 6$ and the price adjustment cost $\gamma = 3$, which are common values in literature of a new Keynesian model. The values of these parameters do not have large effects on the quantitative results. The most difficult and quantitatively important parameter is the productivity difference between industries. As I described in the introduction, growth rates in productivity in the Japanese manufacturing sector were much higher than those in the Japanese non-manufacturing sector from the early 1990s to 2000s. Figure 3 shows that productivity for the manufacturing sector is 70 percent higher than that for the non-manufacturing sector even in the case that productivity is assumed to be in the same level as 1980. Given the fact that most consumption goods that old people tend to prefer belong to ones produced by the non-manufacturing sector, I assume that the productivity in Sector 1 is lower than that in other sectors by 25 percent as a conservative value. As a sensitivity analysis, I will also examine the case that the productivity in Sector 1 is lower than that in other sectors by 40 percent.

For the monetary policy rule, I assume that the target inflation rate π^* is 1. Then the steady state interest rate R^* is calculated by $R^* = \pi^*/\beta$. I set the sensitivity of the policy rate to inflation, $d_\pi = 1.2$, which is common in monetary DSGE models using Japanese data.[9] Also I set $d_y = 0$ for simplicity because this parameter barely affects quantitative results.

For labor market parameters, I set a job destruction rate $\delta = 0.0125$ based on the fact that about 5 percent of Japanese workers change their jobs in a given year. For the parameters in the matching function, I estimate the following matching function for each job type using Japanese data,

$$\log(\#\text{of new hires}_k) = \log(s_k) + \phi \log(\#\text{of job offers}_k) + (1 - \phi) \log(\#\text{of unemployed workers}).$$

where k represents a job type. See Appendix for more detail about data I use for the estimation. According to the estimation result, I set $\phi = 0.456$. For the matching efficiency by sector, I do not have rich data for the number of matches and the number of job offers by sector. Thus I assume that the "medical jobs" and "service jobs" correspond to Sector 1 because these types of job are typically needed in the sector and set s_1 to one third of s_2 and s_3 according to the estimation result for these two job types and others.[10] I choose the

[9]For example, see Fueki et al. (2010).

[10]The reason why the matching efficiency is lower for "medical jobs" and "service jobs" is beyond the

average matching efficiency so that the aggregate unemployment rate is equal to 4 percent in a steady state.

3.2 Future Path of α_k

In this subsection, I calculate a forecast path of $\alpha_{k,t}$, the weight of each consumer product in the consumption basket, so that they are consistent with both the Japanese demand structure by age group and the future path of age structure in Japan. As I already mentioned, I represent a change in demand structure caused by population aging as a change in $\alpha_{k,t}$. In this sense, $\alpha_{k,t}$ is not considered as a constant parameter but a variable changing exogenously over time in this quantitative analysis. I set 1992 to the initial period and increase $\alpha_{1,t}$ and decrease $\alpha_{2,t}$ while satisfying $\alpha_{1,t} + \alpha_{2,t} + \alpha_{3,t} = 1$ as the ratio of old population to total population in the economy increases.

The first step to calculate the forecast path of $\alpha_{k,t}$ is to compute a typical consumption basket by age group. I classify all households into either of the two age groups with the dividing line at 60 years old. A household is classified as "young household" if a person representing the household is younger than 60 years old and is classified as "old household" otherwise. Then I compute the ratio of each consumer product expenditure to total consumption expenditure by age group, $\theta_{i,a}$, as follows:

$$\theta_{i,a} \equiv \frac{c_{i,a}}{c_a} \quad \text{where} \quad c_a = \sum_i c_{i,a}. \tag{17}$$

$c_{i,a}$ represents the consumption expenditure for product i of age group a.[11] Using these ratios, I make an index for each product, χ_i, by subtracting the ratio for a young household from the ratio for an old household,

$$\chi_i \equiv \theta_{i,o} - \theta_{i,y}$$

For instance, if Product A has 40 percent share of total consumption expenditure for an old household and has 30 percent for a young household, the index is calculated as 10 (= 40-30). Thus a high index value for Product A means that old people tend to prefer the Product A compared with young people. Finally, I classify all consumer products into one of the three categories of consumption goods according to the index. Remember that I

scope of this paper, but I assume that this is partly because (1) they need some official qualifications, (2) they are subject to relatively strict public regulation.

[11] I construct the typical consumption basket by age group, $c_{i,a}/c_a$, using "Family Income and Expenditure Survey." I construct the consumption basket by age group for each year and use its average from 2002 to 2010. The data is available at `http://www.stat.go.jp/english/data/kakei/index.htm`.

categorize Sector 1 (Sector 2) as an industry producing consumption goods that old (young) people relatively prefer. Thus I classify Product A as consumption goods produced in Sector 1 (Sector 2) if the index value for Product A, χ_A, belongs to the top (bottom) one third among all consumption goods. Figure 4 shows that while consumption goods produced in Sector 1 and 2 account for 49 percent and 34 percent of total consumption expenditure of an old household, they account for 32 percent and 52 percent for a young household, implying a substantial difference in the demand structure between an old and a young household.[12]

The second step is to compute a forecast path for demand structure of the economy using the typical consumption basket by age group (Figure 4) and the forecast path for age structure (Figure 1). Let $c_{k,t}$ denote the expenditure of consumption goods produced in industry $k = 1, 2$, and 3, and $c_t = \sum_{k=1}^{3} c_{k,t}$. Then we have

$$\frac{c_{k,t}}{c_t} = \eta_t \theta_{k,o} + (1 - \eta_t)\theta_{k,y}$$

where η_t is the ratio of the population over 60 years old to the population over 20 years old in time t and $\theta_{k,a}$ (a = young, old) is the ratio of the expenditure for consumption goods produced in industry k to total consumption expenditure by age group. This ratio is constructed in the same manner as (17),

$$\theta_{k,a} \equiv \frac{\sum_{i \in k} c_{i,a}}{c_a} \quad \text{where} \quad c_a = \sum_k \sum_{i \in k} c_{i,a}.$$

As I assume that the typical consumption basket by age group, $\theta_{k,a}$, does not change over time in this quantitative analysis, the demand structure of the economy, $c_{k,t}/c_t$, is affected only by a change in age structure.

The third and final step is to map the forecast path for demand structure, $c_{k,t}/c_t$, into a forecast path for $\alpha_{k,t}$. First, I numerically compute the path of $\alpha_{k,t}$ so that it achieves the demand structure calculated in the second step at the converged point of the forecast, $c_{k,T}/c_T$, where T is a number large enough to have the path converged. The value of $\alpha_{k,t}$ at the converged point is denoted by $\alpha_{k,T}^{\tau}$ where τ represents the year when each forecast was formulated ($\tau = 1992, 1997, 2002$, and 2006). Second, I compute α_k that achieves the demand structure of the economy in 1992 and denote it $\alpha_{k,1992}$. Third, I assume that the

[12] If the supply-side of the economy does not respond smoothly to changes in the demand structure as this paper argues, the values in Figure 4 do not represent the optimized consumption basket but represent the consumption basket during the transition period. If the consumption basket during the transition period were to be more precisely reflected in the simulations, the economy would be faced with an even larger shift in demand structure with a larger discrepancy across the two age groups, suggesting that this quantitative exercise may underestimate the effects of population aging.

gap between $\alpha_{k,1992}$ and $\alpha_{k,T}^{1992}$ tapers off according to an AR1 process,

$$(\alpha_{k,T}^{1992} - \alpha_{k,t}^{1992}) = \xi(\alpha_{k,T}^{1992} - \alpha_{k,t-1}^{1992}) \text{ where } 0 < \xi < 1,$$

and draw a converging line between the two values. To this end, I choose the AR1 parameter so that the converging line fits the data. The computed path of $\alpha_{k,t}$ is denoted by $\{\alpha_{k,t}^{1992}\}_{t=1992,1993,\cdots,T}$. Fourth, I make the forecast path which starts at $\alpha_{k,1997}^{1992}$ and converges to $\alpha_{k,T}^{1997}$ in the same manner. The spirit of this procedure is that the forecast path of age structure was unexpectedly revised in 1997 and people came to believe that $\alpha_{k,t}$ would converge to the new level, $\alpha_{k,T}^{1997}$. The new forecast path is denoted by $\{\alpha_{k,t}^{1997}\}_{t=1997,1998,\cdots,T}$. Similarly, I compute the forecast path for $\{\alpha_{k,t}^{2002}\}_{t=2002,2003,\cdots,T}$ and $\{\alpha_{k,t}^{2006}\}_{t=2006,2007,\cdots,T}$. Figure 5 shows $\{\alpha_{1,t}^{\tau}\}_{t=\tau,\tau+1,\cdots,T}$, the weight of Sector 1, for $\tau = 1992, 1997, 2002$, and 2006. The figure shows that while the weight of consumption goods produced in Sector 1 was supposed to converge to 0.38 according to the forecast made in 1992, it was revised upward to 0.392 in 1997, 0.400 in 2002, and 0.411 in 2006, reflecting the faster-than-expected population aging in Japan. Note that the shape of the forecast paths in Figure 4 looks similar to Figure 1, implying that this parameterized forecast path of $\alpha_{k,t}$ fits the data well.

3.3 Simulation

I set 1992 as the initial period. The procedure of the simulation is as follows. First, I insert $\{\alpha_{k,t}^{1992}\}_{t=1992,1993,\cdots,T}$ into the model and calculate a transition path of endogenous variables.[13] The paths of endogenous variables are denoted by $\{X_t^{1992}\}_{t=1992,1993,\cdots,T}$. Second, I insert $\{\alpha_{k,t}^{1997}\}_{t=1997,1998,\cdots,T}$ into the model and compute a transition path of endogenous variables using X_{1997}^{1992} as their initial values. The paths are denoted by $\{X_t^{1997}\}_{t=1997,1998,\cdots,T}$. Similarly, I compute $\{X_t^{2002}\}_{t=2002,2003,\cdots,T}$ and $\{X_t^{2006}\}_{t=2006,2007,\cdots,T}$ and use $\{X_{1992}^{1992}, \cdots, X_{1996}^{1992}, X_{1997}^{1997}, \cdots, X_{2001}^{1997}, X_{2002}^{2002}, \cdots, X_{2005}^{2002}, X_{2006}^{2006}, \cdots, X_T^{2006}\}$ as the final output of the quantitative analysis.

4 Result

In this section, I describe how aggregate variables change in the response to the changes in demand structure caused by population aging in Japan. In particular, I describe the responses of the aggregate variables when the aggregate demand shifts from Sector 2, which produces consumption goods that young people tend to prefer, to Sector 1, which produces consumption goods that old people tend to prefer. I first describe the responses of real

[13] I assume that they are at their steady state in 1992.

economic variables such as unemployment rates and output, and then describe the response of inflation. I show the responses without the upward revisions of the forecast for the speed of population aging in addition to those with the revisions. By doing so, I show how these revisions contribute to the persistence of the responses.

4.1 Real Economic Activity

Figure 6 shows the responses of unemployment rates. The bold line is the response with revisions in the forecast of population aging. Other lines represent the responses of unemployment rates in the case that the forecasts made in 1992, 1997, and 2002 were not revised and continued to be relevant until T. Some comments are in order. First, the unemployment rate is about 4.2 percent, which is higher than the initial value by 0.2 percent point, at the converged point. The reason why the changes in demand structure push up the steady state unemployment rate is that the matching between labor supply and demand in Sector 1 is less efficient than that in the other two sectors. Second, unemployment rates sharply increase after the revisions in the forecast for population aging and then slowly decrease and converge. This response of unemployment rates implies that employees working in Sector 2 shift to Sector 1 in the response to the changes in demand structure, but some of them are unemployed for a while due to labor market frictions. Third, the revisions in the forecast for population aging repeatedly push up the unemployment rates and keep them around 4.3 to 4.4 percent, which are higher than the steady state level, in the last thirty years.

Figure 7 shows the response of real GDP to the changes in demand structure. The figure shows that real GDP decreases gradually and converges to 1.8 percent point lower level than the initial level. There are two reasons for the gradual decrease in real GDP. First, the aggregate labor input decrease due to the rise in unemployment rates as I described above. Second, as labor force shifts from Sector 2 to Sector 1 to meet the demand shift, the aggregate productivity falls because productivity of firms in Sector 1 is lower than that of firms in Sector 2. That is, labor force shifts from a high productivity sector to a low productivity sector because demand in the low productivity sector increases compared with the high productivity sector.

In summary, unemployment rates rose and remained at a high level for thirty years from the early 1990s in Japan in the response to population aging and the revisions in its forecast. At the same time, real GDP gradually declined due to the increase in unemployment rates and the decrease in the aggregate productivity caused by resource reallocation. These results are consistent with the data in the following aspects. First, Figure 2 indicates that Japanese structural employment rates started to rise in the early 1990s and have remained at a high level. While the magnitude of the responses in this paper is much smaller than that of the rise in the data, the result implies that population aging could explain a part of the rise in Japanese structural unemployment rates and could cause a decline in labor supply. Second, Figure 3 indicates that productivity *increases* in the manufacturing sector while labor input *decreases* in the manufacturing sector in comparison with the non-manufacturing sector from the early 1990s. The figure implies that while the Japanese economy experienced continuous structural changes in the past, it faced a decrease in aggregate productivity caused by significant resource reallocation from high productivity industries to low productivity ones particularly from the early 1990s, which is consistent with the result of this paper.

As a number of studies using aggregate data show that Japanese economy was in recession in the 1990s mainly because of a sudden slowdown in aggregate productivity growth and a decline in labor input, the result in this paper suggests that population aging could be one of reasons for them.[14] An interesting point is that the resource reallocation between industries increases structural unemployment rates and has negative effects on aggregate productivity, but it obviously has *positive* effects on social welfare in this model because the reallocation occurs as a result of optimization and meets the demand shift. Thus the result implies that the slowdown in productivity growth and the increase in structural unemployment rates in Japan might occur in line with welfare improvement.

4.2 Inflation

Figure 8 shows the response of inflation. The figure shows that inflation negatively responds to the repeated upward revisions in the forecast for the speed of population aging and gradually returns to zero inflation.[15] On average, the changes in demand structure with the repeated upward revisions in the forecast for the speed of population aging induce around 0.2 to 0.3 percent point deflationary pressures except for the response in 1992.[16] Note

[14]Hayashi and Prescott (2002) first pointed out that the Japanese recession in the 1990s could be explained by a slowdown in aggregate productivity growth and a decrease in labor input. See Hayashi (2007) for more details about the Japanese recession in the 1990s and the background of the recession.

[15]Some may think that the response of inflation with spikes every five years looks strange and unrealistic. In the real economy, however, since birth rates, which are the most relevant determinants of age structure in the future, are announced every year, the household and the firm should have more chances to recognize the revisions and respond to the changes more smoothly. Even if people had more chances to recognize the revisions, it would make the spikes smaller and more frequent, but would not change the magnitude of the quantitative result.

[16]The response of inflation in 1992 (the initial period) is much larger than the responses in 1997, 2002, and 2006. This is because I assume that the Japanese economy was in its steady state and Japanese population aging suddenly and unexpectedly started in 1992. Since this assumption is just for computational tractability,

that while the deflation period lasted for a while, each response of inflation to the revision is not that persistent. This result suggests that the deflationary pressure from the 1990s to the 2000s has been persistent because the forecast for population aging was repeatedly revised upward and these revisions have worked as unexpected macroeconomic shocks to the economy. Intuitively speaking, this result implies that the Japanese economy has faced a persistent deflationary pressure because people did not notice the seriousness of population aging at first and then have recognized it gradually as their beliefs were revised.

Figure 9 shows inflation rates by sector. The dashed and bold line is the response of inflation in Sector1 and 2, respectively. The figure shows that the deflationary pressure is stronger in Sector 2 than that in Sector 1 after the shocks, implying that the changes in demand structure also induce the changes in relative prices between sectors. Given the fact that demand shifts from Sector 2 to Sector 1, the response of relative prices is intuitive.

While it is easy to understand why the changes in demand structure induce the changes in relative prices between industries, it is not straightforward to understand why the changes in demand structure induce a deflationary pressure on a general price. A key to understanding the deflation is the *gradual* decline in real GDP. As real GDP gradually declines, the *growth rate* of real GDP is lower than its steady state growth rate for a while, implying that a natural interest rate is also lower than its steady state level during these low growth periods.[17] Since I assume that the monetary authority does not respond to the decline in the natural interest rate but respond only to inflation and output gap, the real interest rate (the nominal interest rate minus inflation) remains higher than the natural interest rate during these low growth periods. This gap between the real interest rate and the natural interest rate makes a consumption goods market tight (i.e., generates negative output gap) and causes a deflationary pressure through a new Keynesian Phillips-curve.

4.3 Sensitivity Analysis

The quantitative results reported in the previous section vary depending on the parameter values. In particular, the productivity gap between Sector 1 and other sectors is critical because higher productivity gap would give rise to lager declines in the aggregate output through more costly resource reallocation. In this subsection, I try an alternative value for the productivity gap as a sensitivity analysis. While I set the productivity gap to 25

it is misleading to focus on the response in 1992.

[17] As is shown in Equation (23) on p. 49 of Gali (2008), the natural interest rate is lower than its steady state value ($=1/\beta$) when the *growth rate* of output under flexible prices is negative. Therefore, since the *gradual* decrease in the level of real GDP induces negative growth rates of output under flexible prices *for a while*, it also induces the natural interest rates lower than its steady state values for a while.

percent in the baseline calibration, here I choose the gap of 40 percent, which is larger than the baseline calibration. The choice of the larger gap is motivated by the fact indicated in Figure 3 where a lager productivity gap is observed between the two industries. Figure 10 and 11 show the results for the case that the productivity in Sector 1 is lower than that in other sectors by 40 percent. Figure 10 shows that real GDP declines gradually and converges to a 3.0 percent lower level than the initial level. As expected, the decline in real GDP is larger than that in the baseline result. Figure 11 indicates the response of inflation. On average, there are 0.4 to 0.5 deflationary pressures underway, which are larger than the baseline result. These figures reconfirm that the quantitative implication somewhat varies depending on the calibrated values for the productivity gap, but the qualitative implication of the model remains fairly unaffected.

5 Conclusion

In this paper I investigate effects of changes in demand structure caused by population aging on real economic activity and inflation using a multi-sector new Keynesian model with job creation/destruction. I consider repeated upward revisions in the forecast for the speed of Japanese population aging as unexpected shocks to demand structure. The main finding in this paper is that the changes in demand structure induce (1) about 0.2 percent point permanent increase and 0.1 to 0.2 percent point transitory increase in unemployment rates, (2) 1.8 percent point permanent decrease in real GDP, (3) 0.2 to 0.3 percent point transitory deflationary pressure on year-to-year inflation, from the early 1990s to 2000s in Japan. Moreover, the repetition of the upward revisions in the forecast for the speed of population aging made those effects look more persistent.

There are two major caveats for the above result. First, the quantitative result depends on quantitative assumptions about parameter values in the model such as the difference in productivity and matching efficiency between industries. Thus the result should be utilized considering the possibility that it may change depending on the quantitative assumptions. Second, I assume the closed economy in this paper. In the real economy, however, because exports to foreign countries account for a substantial part of the aggregate demand, effects of the changes in domestic demand structure may be smaller than computed in this paper. Extending the model to an open economy is an interesting future topic for research.

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Appendix: Estimation of Matching Function

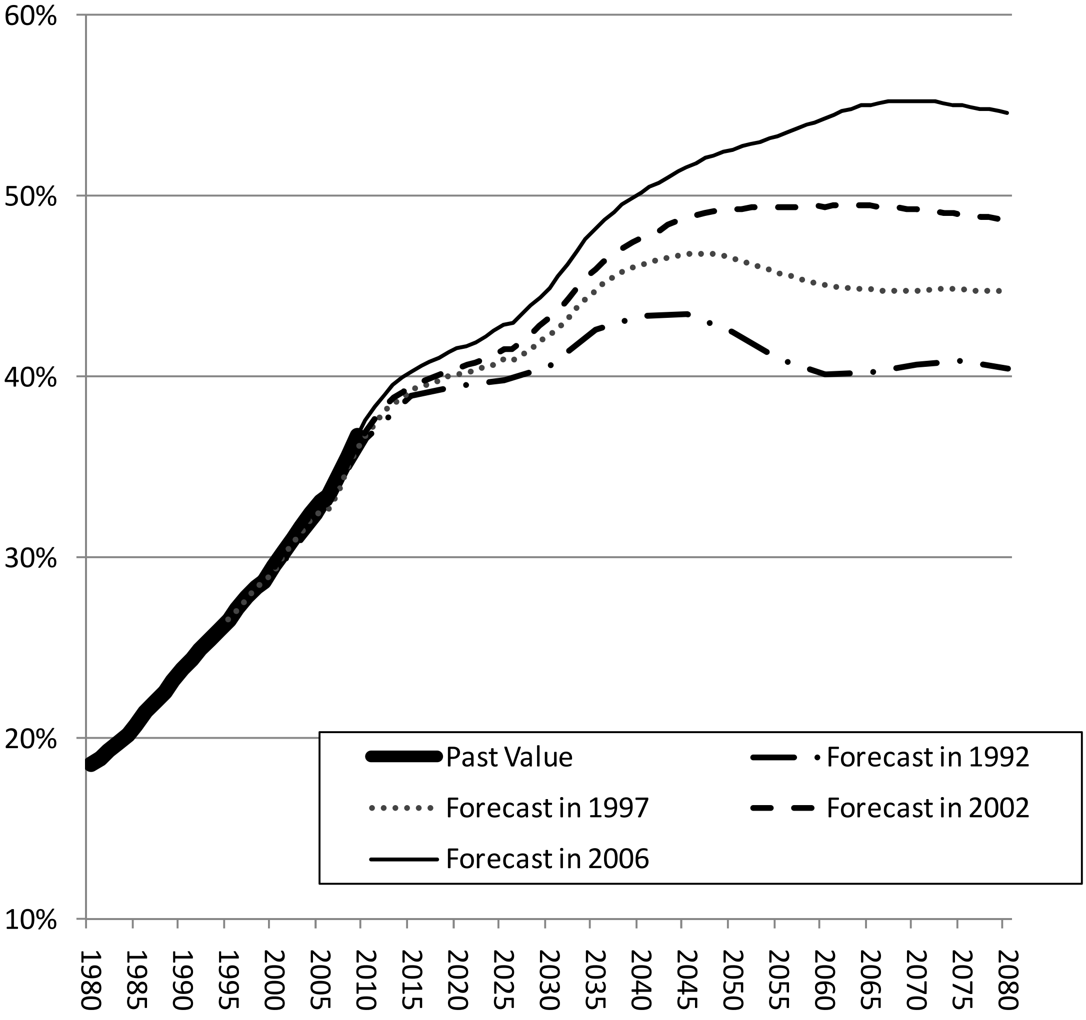
I estimate the following matching function for calibration,

$$\log(\#\text{of new hires}_k) = \log(s_k) + \phi \log(\#\text{of job offers}_k) + (1-\phi)\log(\#\text{of unemployed workers})$$

where k represents a type of job. I use seasonally adjusted monthly data from April 2000 to January 2011 for the number of new hires, the number of job offers, and the number of unemployed workers. For the number of new hires and the number of job offers, I use the number of "persons who found employment (cases)" and the number of "monthly active offers (excluding part time jobs)" in "Employment Referrals for General Workers" available at the website of the Ministry of Health, Labor and Welfare.

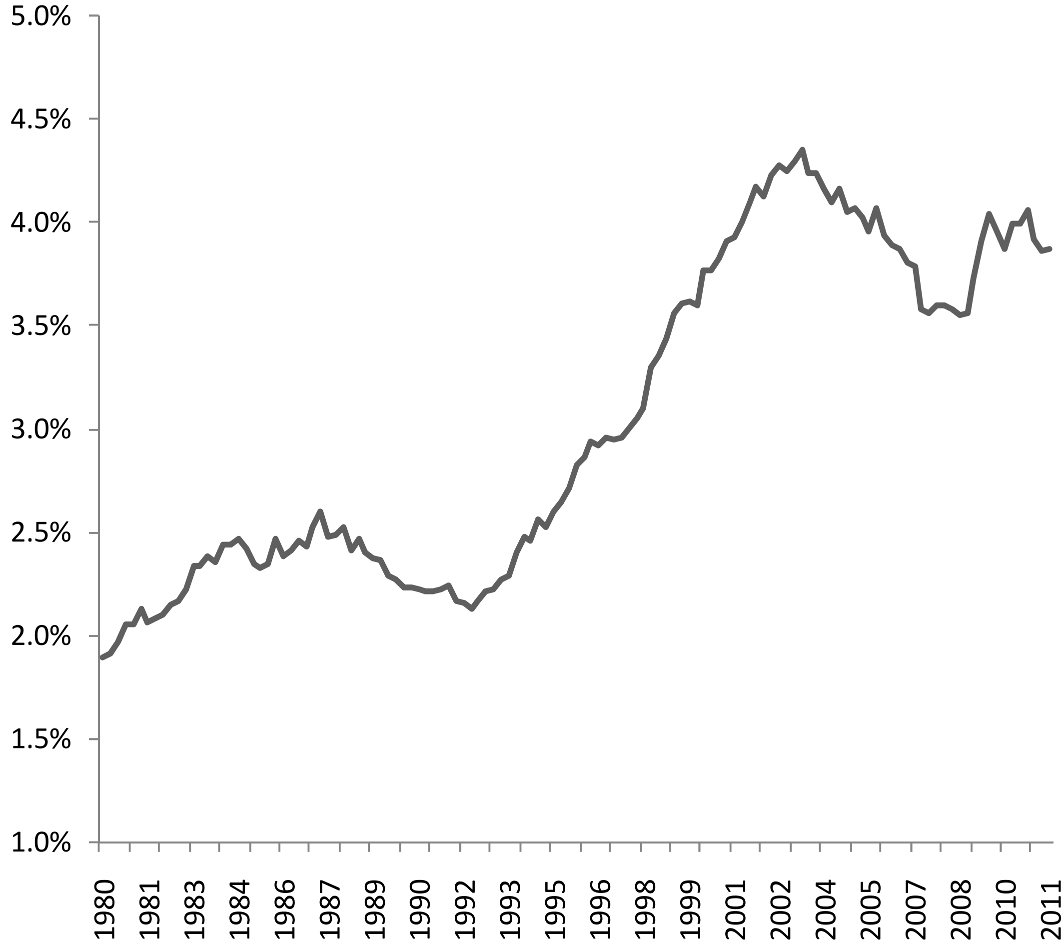
I first estimate the matching function using aggregate data and obtain $\hat{\phi} = 0.456$. Then I insert the number of matches and the number of job offers for "medical jobs" and "service jobs" into the matching function and calculate the matching efficiency for these types of job as a residual of the matching function. Similarly, I compute the matching efficiency for other types of job and use the ratio between two values for calibration of the difference in matching efficiency between industries.

Figure 1: Forecast for Population Aging



Note: The figure shows the forecasts for the ratio of the population over 60 years old to the population over 20 years old in Japan. The forecasts are constructed by National Institute of Population and Social Security Research based on the latest national census at that time. The data is available at `http://www.ipss.go.jp/index-e.asp`.

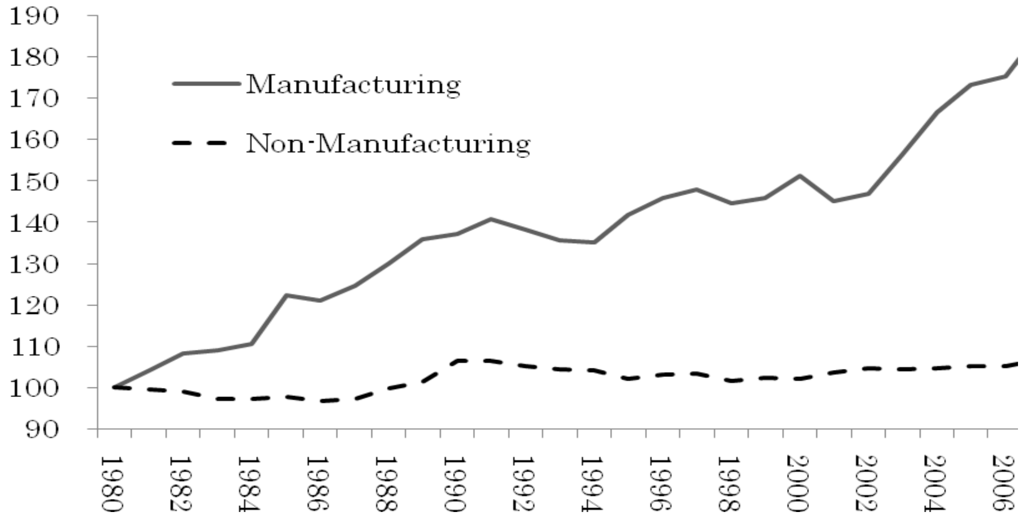
Figure 2: Structural Unemployment Rate



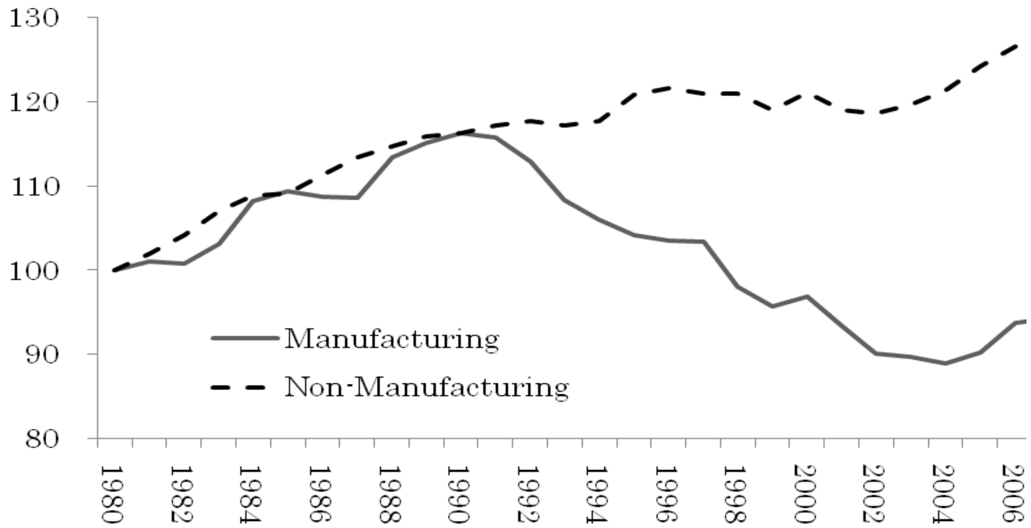
Note: This figure shows the development of Japanese structural unemployment rates in the last thirty years. They are estimated by Ministry of Health, Labour and Welfare, "Report on Employment Service" and Ministry of Internal Affairs and Communications, "Labour Force Survey."

Figure 3: Productivity and Labor Input

<Productivity (1980 = 100)>

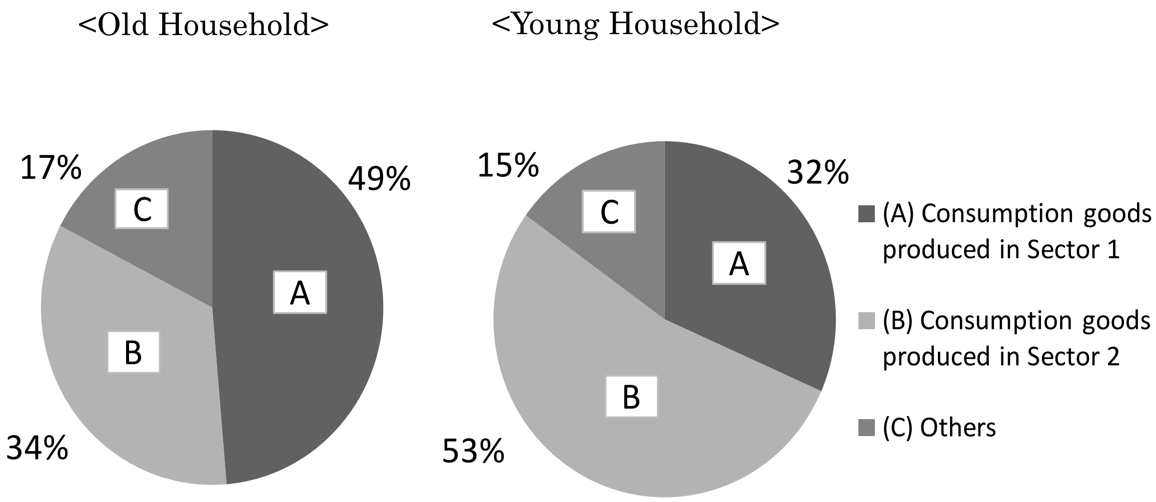


<Labor Input (1980 = 100)>



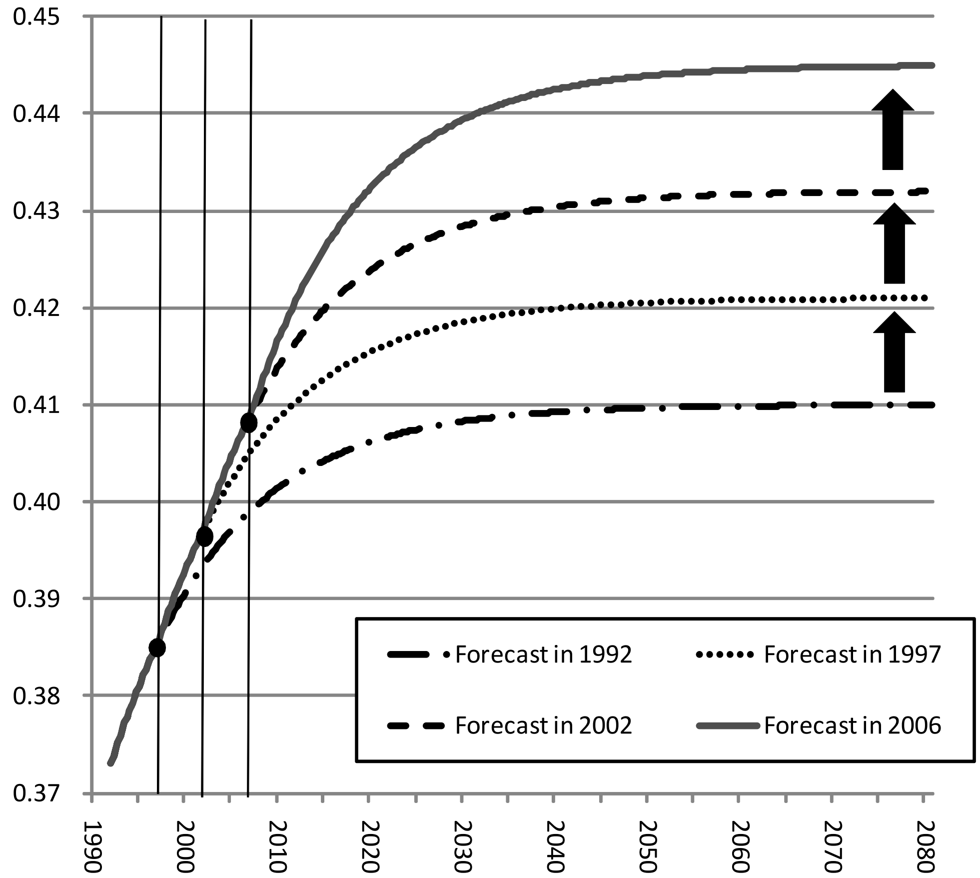
Note: Productivity is calculated by a growth rate of measured TFP. Both figures use Japan Industrial Productivity Database 2011 (JIP 2011) at Research Institute of Economy, Trade, & Industry (RIETI).

Figure 4: Demand Structure by Age



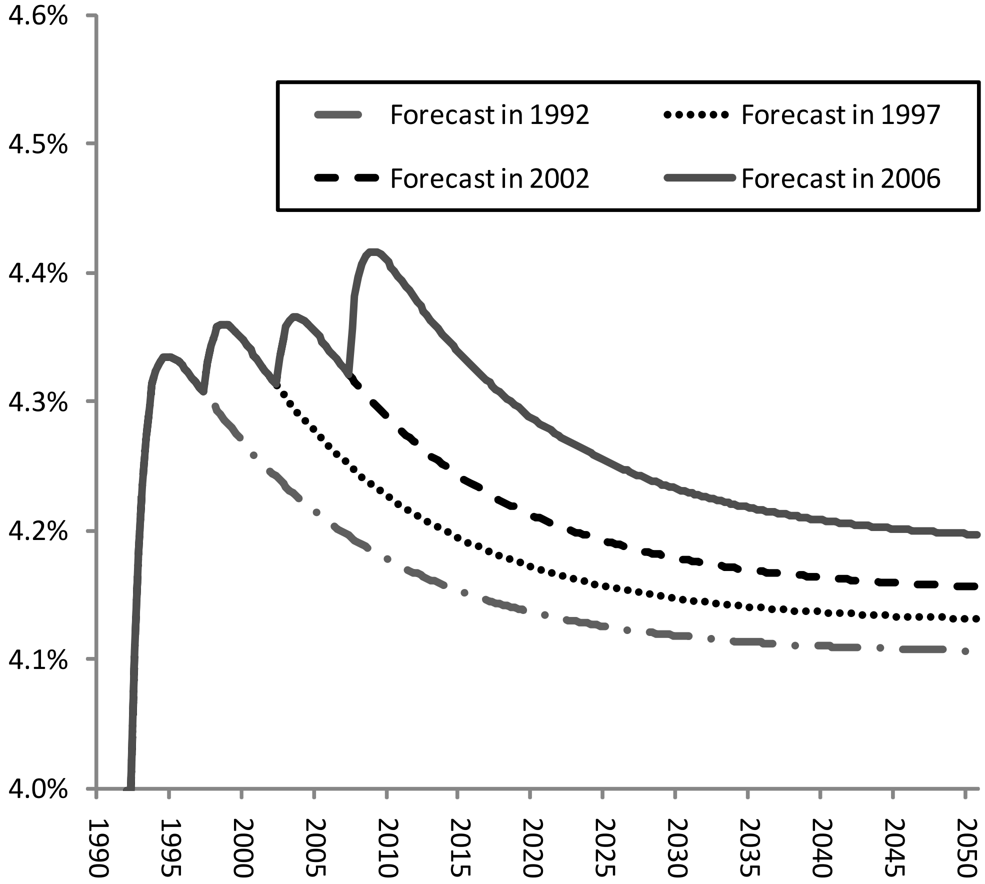
Note: I classify all households into either of the two age groups with the dividing line at 60 years old. A household is classified as "young household" if a person representing the household is younger than 60 years old and is classified as "old household" otherwise. Then I compute the ratio of each consumer product expenditure to total consumption expenditure by age group. I construct the ratio using ``Family Income and Expenditure Survey" at `http://www.stat.go.jp/english/data/kakei/index.htm`. I first construct the ratio by age group for each year and use its average from 2002 to 2010. Using these ratios, I make an index for each consumer product by subtracting the ratio for a young household from the ratio for an old household. For instance, when Product A has 40% share of total consumption expenditure for an old household and it is 30% for a young household, the index is 10 (= 40-30). Thus a high index value for Product A means old people tend to prefer the Product A compared with young people. Finally, I classify all consumer products into one of three categories of consumption goods according to the index. That is, I classify Product A as consumption goods produced in Sector 1 (Sector 2) if the index value for Product A belongs to the top (bottom) one third among all consumption goods.

Figure 5: Future Path of α_1



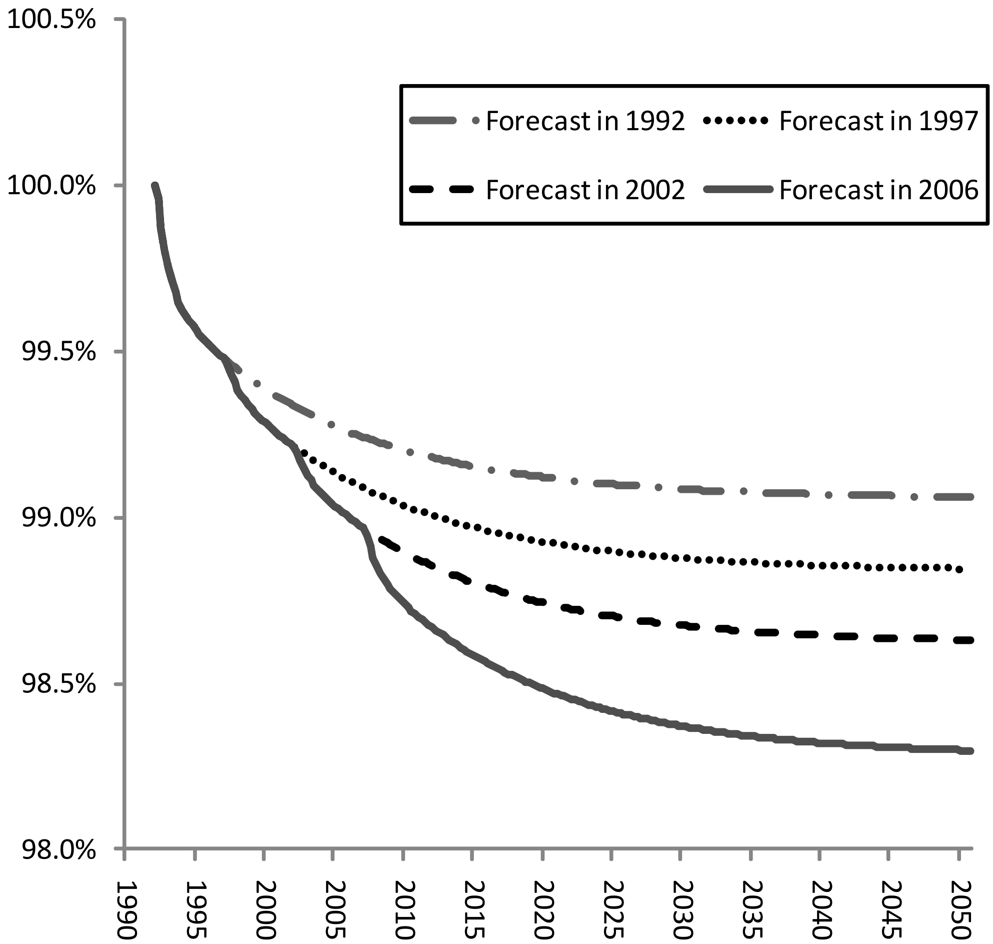
Note: The figure shows the path of the weight of consumption goods produced in Sector 1 in the consumption basket. It shows that while the weight on consumption goods produced in Sector 1 was supposed to converge 0.38 according to the forecast made in 1992, it was revised upward to 0.392 in 1997, 0.400 in 2002, and 0.411 in 2006, reflecting the Japanese population aging faster than expected.

Figure 6: Unemployment Rate



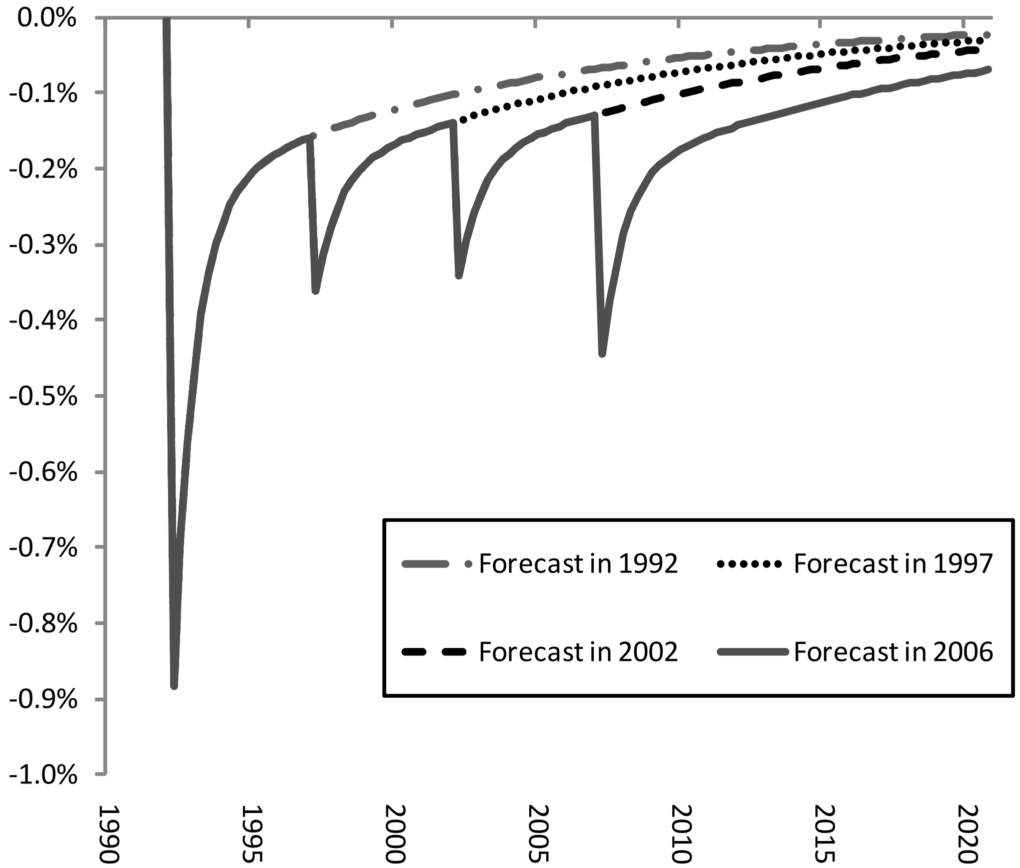
Note: The figure shows the responses of unemployment rates. The bold line is the response with revisions in the forecast of population aging. Other lines represent the responses of unemployment rates in the case that the forecasts made in 1992, 1997, and 2002 were not revised and continued to be relevant.

Figure 7: Real GDP



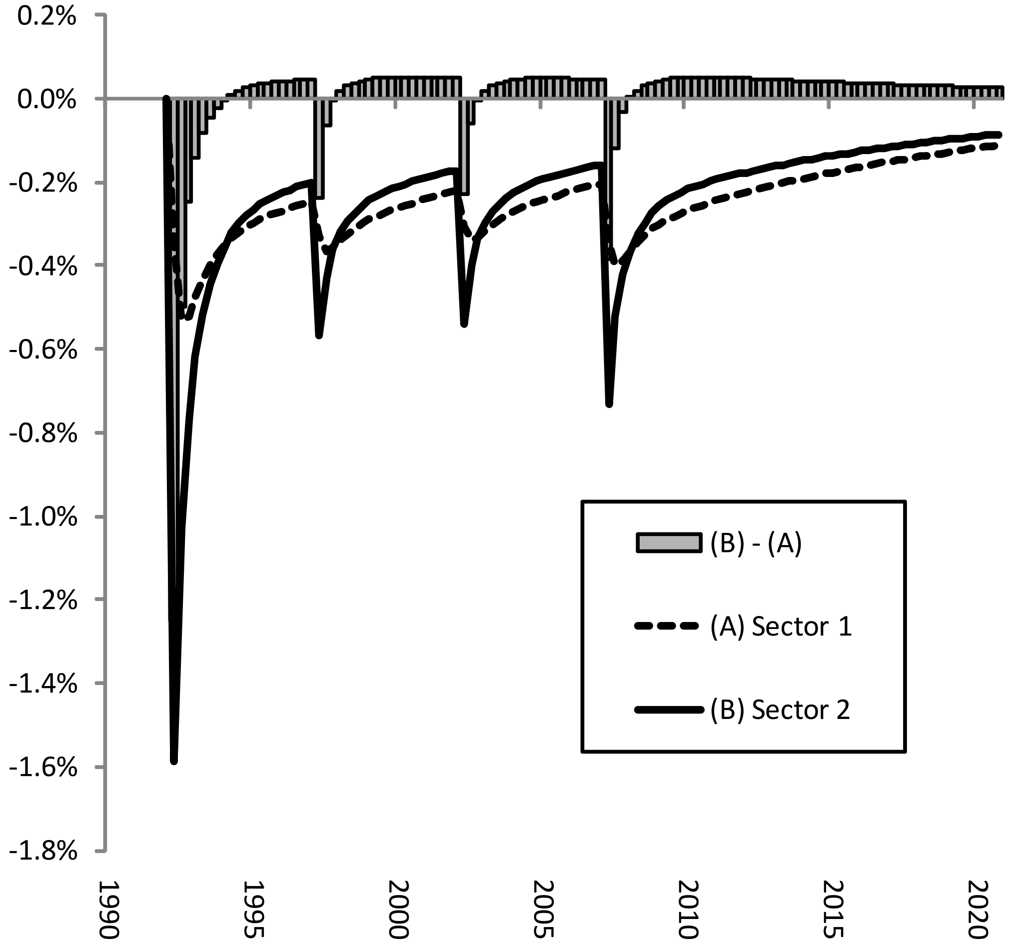
Note: The figure shows the responses of real GDP. The bold line is the response with revisions in the forecast of population aging. Other lines represent the responses of real GDP in the case that the forecasts made in 1992, 1997, and 2002 were not revised and continued to be relevant.

Figure 8: Inflation Rate (CPI)



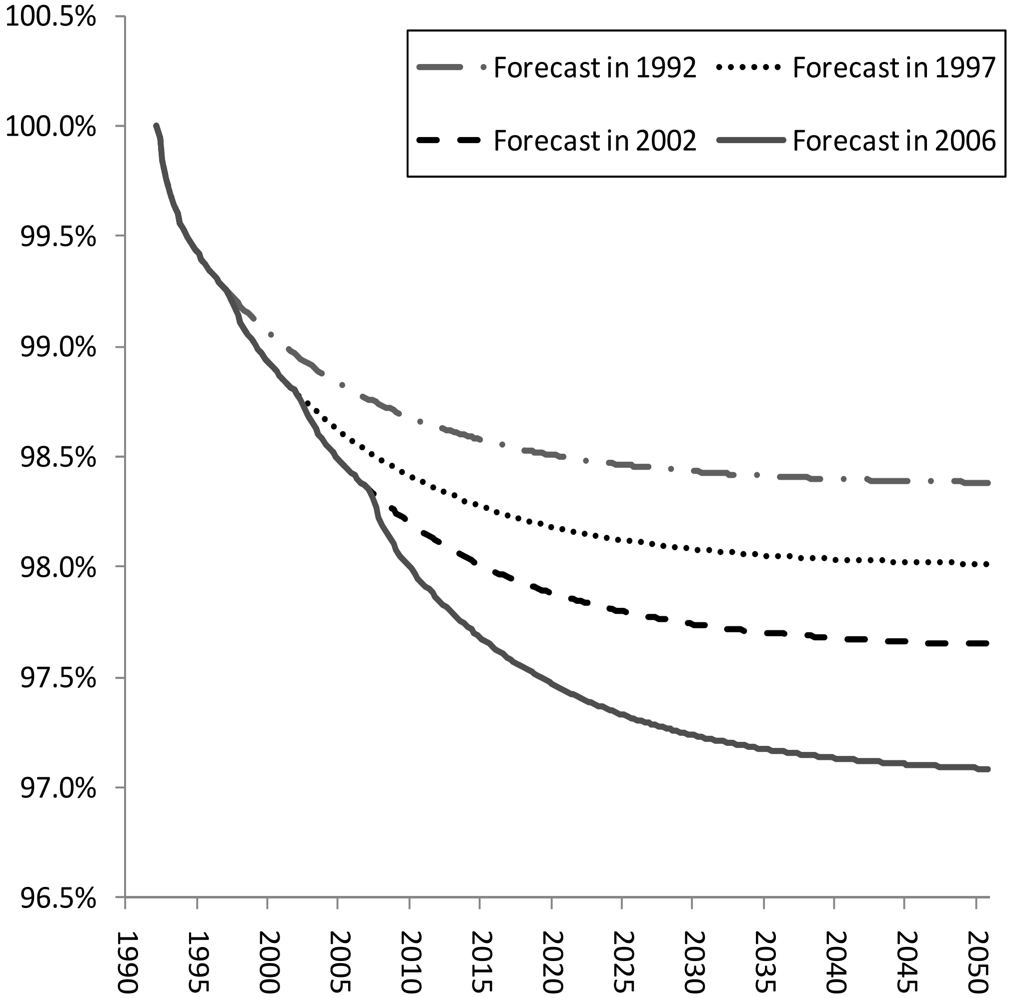
Note: The figure shows the responses of inflation rate in CPI. The bold line is the response with revisions in the forecast of population aging. Other lines represent the responses in the case that the forecasts made in 1992, 1997, and 2002 were not revised and continued to be relevant.

Figure 9: Inflation (Relative Prices)



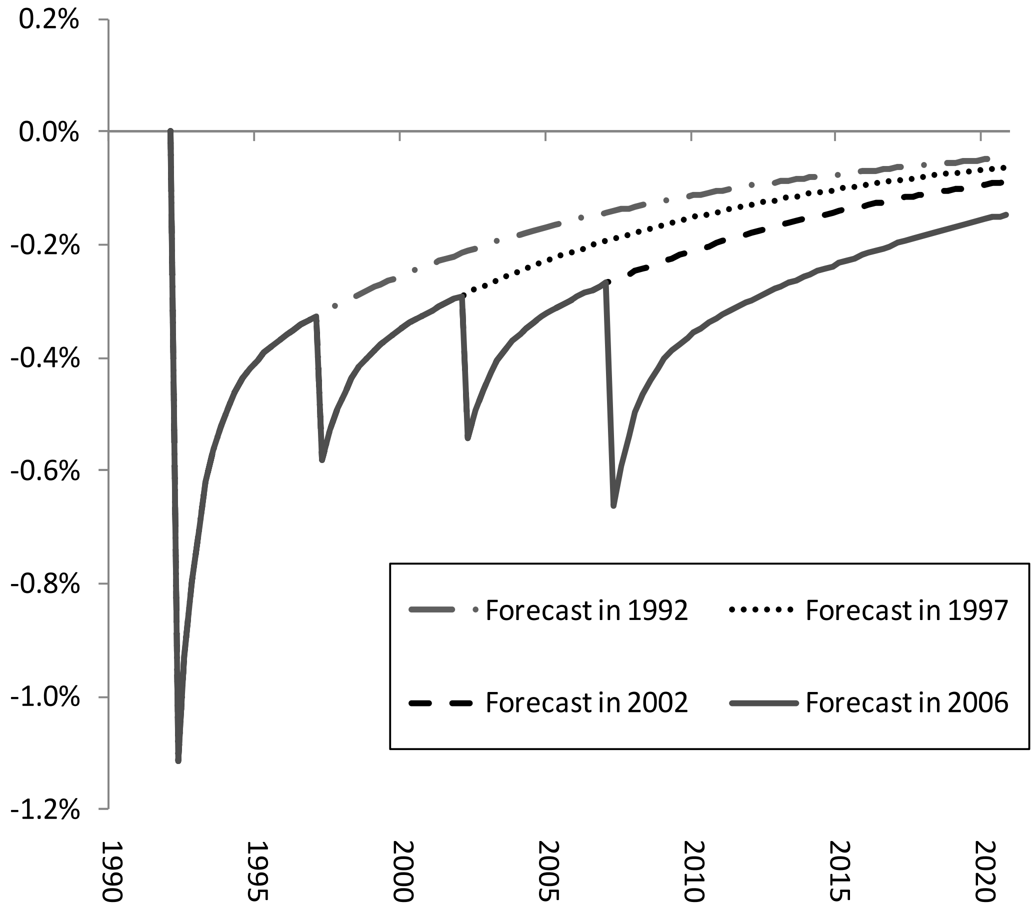
Note: The figure shows the responses of inflation by industry. The dashed and bold line is the response of inflation in Sector1 and 2, respectively. The bars are the difference between inflation rates in Sector 1 and 2.

Figure 10: Real GDP (Large Productivity Gap)



Note: The figure shows the responses of real GDP. The bold line is the response with revisions in the forecast of population aging. Other lines represent the responses of real GDP in the case that the forecasts made in 1992, 1997, and 2002 were not revised and continued to be relevant.

Figure 11: Inflation Rate (CPI, Large Productivity Gap)



Note: The figure shows the responses of inflation rate in CPI. The bold line is the response with revisions in the forecast of population aging. Other lines represent the responses in the case that the forecasts made in 1992, 1997, and 2002 were not revised and continued to be relevant.