Analyzing Multi-Sectoral Effects of Demographic Change on the Japanese Economy

TAKASHI YANO
Keio Research Institute at SFC, Keio University, 5322 Endo, Fujisawa, Kanagawa 252-8520 Japan
E-mail: arrowfield@gol.com

HIROYUKI KOSAKA
Faculty of Policy Management, Keio University, 5322 Endo, Fujisawa, Kanagawa 252-8520 Japan
E-mail: hkosaka@sfc.keio.ac.jp

KEYWORDS: Commodity demand and industrial structures; Demographic change; Japanese economy

1. Introduction

This paper deals with the effects of population decrease and policies induced by demographic change on commodity demand and industrial structures with special reference to the Japanese economy.

Although it is not a major factor, Horioka (forthcoming) shows that the low growth of household consumption expenditure is a significant cause for the low economic growth of the Japanese economy during the 1990's, the so-called "lost decade."[1] Since household consumption expenditure is a major component of the GDP; *i.e.*, its share in the GDP is approximately 60 percent, its stagnation can easily lead to the stagnation of the whole economy. In other words, it is imperative for the stable economic growth to be accompanied with the stable growth of household consumption expenditure. Observing the current Japanese economy, there are factors which have substantial effects on the stability of household consumption expenditure; they are population decrease and aging. Population decrease will lead to the decrease in the total amount of household consumption. Aging has three effects on household behavior. First, the life cycle-permanent income hypothesis implies that the saving rate would decline due to aging. Whether the overall effect of this implication results in the increase of household consumption is unclear; however, given the other factors unchanged, the decrease of the saving rate leads the increase of consumption expenditure. Second, on the contrary, a theory on precautionary savings indicates that the saving rate would go up because of future uncertainties. As for these two effects, applying the lice cycle-permanent income hypothesis to data of Japan, Koga (2005) finds that aging and future uncertainties contribute to decrease and increase of the saving rate, respectively. Murata (2003) also shows that uncertainties on social security benefits increase the saving rate in Japan. Finally, preferences would change over time and age. Wakabayashi (2001, 2002) demonstrates that commodity demand structures and preferences are not identical across age groups by using an almost ideal demand system.

As we reviewed the literature on the effects of demographic change, several analyses can be found for each single economic variable (e.g. the saving rate). On the contrary, in large-scale economic modeling, demographic change has not been focused seriously for some reasons despite its importance. Due to population decrease and aging particularly in developed countries, however, demographic issues are becoming one of the major topics for analyses by large-scale economic modeling. For instance, Okamoto (2005) apply a single-country general equilibrium model to quantify the macroeconomic effects on the Japanese economy. By contrast, Faruqee and Mühleisen (2003), McKibbin and Nguyen (2004), and Shi and Tyres (2005) employ a multi-country model.[2] Among the three analyses by a global model, Faruqee and Mühleisen (2003) and McKibbin and Nguyen (2004) demonstrate extensive results with respect to Japan. In this paper, we construct a price-linked input-output model for Japan, which is in line with the model in Usami *et al*. (2004). Our model also has general equilibrium nature; however, most parameters are econometrically estimated. Furthermore, we interlink a model which describes household behavior (i.e., consumption-saving decision) for ten age groups of household heads with the input-output model.[3] By applying the model, we analyze the effects of population decrease and the rise in the consumption tax rate on commodity demand and industrial structures.

The rest of the paper consists of three sections. Section 2 explains the structure of the model. Section 3 presents results for final test and simulations. Finally, Section 4 provides conclusions.

2. The Model Structure

The basic structure of the model follows Usami *et al*. (2004). However, our commodity demand model is specifically refined. Moreover, households' savings are also determined by their utility maximization process and the financial sub-model which explains the money supply as well as the long-term interest rate are added.

2.1. The Overall Structure

The model is composed of the four sub-models: household, input-output, financial, and population sub-models.[4] The household sub-model explains consumption for 49 commodities and asset demand disaggregated with respect to 10 age groups of the head of the households. The input-output sub-model determines output and price for 206 sectors simultaneously. The financial sub-model accounts for the money supply and the long-term interest rate. The population sub-model deals with age-grouped population. These sub-models are interlinked and the linkage mechanism is shown in Figure 1.

<Figure 1 around here>

2.2. Household Sub-Model

There is a vast literature regarding commodity demand systems. Stone (1954) estimated a linear expenditure system (LES) which is based on the Klein-Rubin (1947-48) or Stone-Geary utility function.[5] Christensen *et al*. (1975) developed a demand system which is underpinned by a translog utility function. Deaton and Muellbauer (1980) constructed an almost ideal demand system (AIDS) which can be derived from a PIGLOG cost function. Modifying an AIDS, Almon (1996) developed a perhaps adequate demand system (PADS). Among those systems, an AIDS is frequently applied; e.g., Sasaki (1996), Asano (1997), and Wakabayashi (2001, 2002) for cases of Japan. These systems work empirically under a condition that the number of commodities is less than that of observations. Since our model contains 49 commodities and 27 observations, a commodity demand system cannot be applied. Therefore, we constructed a commodity demand model by modifying the model in Ballard *et al*. (1985), which takes a different approach to explain commodity demands.[6]

Households' savings are also determined in the same framework. Whereas Ballard *et al*. (1985) do not consider the households' portfolio selection behavior; the aggregate savings are further divided into safe and risky assets by a portfolio selection model in our model.

2.2.1. Commodity Price and Consumption – Saving Decision

Similar to a standard commodity demand system, the commodity demand model of

Ballard *et al*. (1985) is a static model and is also based on households' utility maximization. Differed to a commodity demand system, their model consists of the current as well as future consumptions. In addition, households are divided with respect to income of a household head. Our household sub-model is formulated in line with Ballard *et al*. (1985); however, ours divides households into ten groups with respect to age of a household head (under 24, 25-29, 30-34, 35-39. 40-44, 45-49, 50-54, 55-59, 60-64, over 65).[7] We discuss the structure of the commodity demand model first. Then, the determinations of household income and commodity price are explained.

In order to construct a commodity demand model, Ballard *et al*. (1985) take the two-step approach. At the first step, the model allocates household's wealth into the aggregate current and future consumptions. Then, the current consumption is further divided into demand for each commodity.

A.Allocation of Household's Wealth Between Current and Future Consumptions

A representative household for the age group y of the head of the household is assumed to have the following constant elasticity of substitution (CES) utility function:

$$U_y = \left[\alpha_y^{1/\sigma_y} \overline{C}_y^{(\sigma_y - 1)/\sigma_y} + (1-\alpha_y)^{1/\sigma_y} C_{Fy}^{(\sigma_y - 1)/\sigma_y}\right]^{\sigma_y/(\sigma_y - 1)}, \tag{1}$$

where $\overline{C}_y = \prod_{k=1}^{49} C_{ky}^{\lambda_{ky}}$ (composite of goods), C_{ky} is demand for commodity k of a household for the age group y, C_{Fy} is the future consumption of a household for the age group y, and α_y and σ_y are parameters.[8] Then, the utility maximization problem can be written as:

$$\begin{aligned} &\max U_y \\ &\text{s.t. } YI_y = \overline{q}_y \overline{C}_y + P_S S_y, \end{aligned} \tag{2}$$

where YI_y is income for a household of age group y, $\overline{q}_y$ is price for the composite goods for a household of age group y, P_S is price for saving, and S_y is saving for a household of age group y.

In this model, households are assumed to purchase capital by their saving and lend it to firms. Letting P_K^H and ζ price for capital and the unit service provided by capital goods, respectively, a household's expected return per unit of saving is given by $P_K^H \zeta$. Since the return of saving is used for purchasing the future good which is assumed to have the same price as the composite goods, we have the following identity:[9]

$$P_K^H \zeta S_y = \overline{q}_y C_{Fy}. \tag{3}$$

Rearranging equation (3) gives:

$$
\begin{aligned}
P_S\, S_y &= \frac{P_S \overline{q}_y}{P_K^H \zeta} C_{Fy} \\
&= P_{Fy} C_{Fy},
\end{aligned}
\tag{4}
$$

where $P_{Fy} = P_S \overline{q}_y \big/ P_K^H \zeta$. Then, applying the result in equation (4), the household's utility maximization problem can be rewritten as:

$$
\begin{aligned}
&\max U_y \\
&\text{s.t. } YI_y = \overline{q}_y \overline{C}_y + P_{Fy} C_{Fy}.
\end{aligned}
\tag{2′}
$$

Solving the utility maximization problem (2′) yields the household's optimal demand for the composite good and future good. The Lagrangian of the household for the age group *y* can be written as:

$$
\begin{aligned}
L_y = &\left[\alpha_y{}^{1/\sigma_y} \overline{C}_y{}^{(\sigma_y - 1)/\sigma_y} + \left(1-\alpha_y\right)^{1/\sigma_y} C_{Fy}{}^{(\sigma_y - 1)/\sigma_y}\right]^{\sigma_y/(\sigma_y - 1)} \\
&+ \mu_y\left(YI_y - \overline{q}_y \overline{C}_y - P_{Fy} C_{Fy}\right),
\end{aligned}
\tag{5}
$$

where μ_y is the Lagrange multiplier of the household for the age group *y*. The first-order conditions are given by:

$$
\alpha_y{}^{1/\sigma_y} U_y{}^{1/(\sigma_y - 1)} \overline{C}_y{}^{-1/\sigma_y} = \mu_y \overline{q}_y, \tag{6}
$$

$$\left(1-\alpha_y\right)^{1/\sigma_y} U_y^{1/(\sigma_y-1)} C_{Fy}^{-1/\sigma_y} = \mu_y P_{Fy}, \tag{7}$$

$$YI_y = \overline{q}_y \overline{C}_y + P_{Fy} C_{Fy}. \tag{8}$$

Combining equations (6) and (7) and substituting the result into equation (8) gives:

$$\overline{C}_y = \frac{\alpha_y YI_y}{\overline{q}_y^{\sigma_y} \Delta_y}, \tag{9}$$

$$C_{Fy} = \frac{\left(1-\alpha_y\right) YI_y}{P_{Fy}^{\sigma_y} \Delta_y}, \tag{10}$$

where $\Delta_y = \alpha_y \overline{q}_y^{1-\sigma_y} + \left(1-\alpha_y\right) P_{Fy}^{1-\sigma_y}$. Substituting equation (10) into equation (4) and rearranging the result yields:

$$S_y = \frac{\left(1-\alpha_y\right) YI_y}{P_S P_{Fy}^{\sigma_y-1} \Delta_y}. \tag{11}$$

B.Allocation of Current Composite Consumption among Detailed Commodities

After obtaining the optimal demand for the current composite good, the optimal demand for each good (49 commodities) is determined by solving the following maximization problem:

$$\max \prod_{k=1}^{49} C_{ky}^{\ \lambda_{ky}} \qquad \text{s.t. } YI_y - P_S S_y = \sum_{k=1}^{49} (1+DCT) q_k C_{ky} \tag{12}$$

where *DCT* is the consumption tax rate and q_k is price for commodity *k*. The Lagrangian for this problem is given by:

$$J_y = \prod_{k=1}^{49} C_{ky}^{\ \lambda_{ky}} + \phi_y \left[YI_y - P_S S_y - \sum_{k=1}^{49} (1+DCT) q_k C_{ky} \right]. \tag{13}$$

The first-order conditions are:

$$\lambda_{ky} \frac{\overline{C}_y}{C_{ky}} = \phi_y (1+DCT) q_k, \quad \text{for } k = 1, 2, \ldots, 49, \tag{14}$$

$$YI_y - P_S S_y = \sum_{k=1}^{49} (1+DCT) q_k C_{ky} \ . \tag{15}$$

Manipulating the first-order conditions yields:

$$C_{ky} = \frac{\lambda_{ky}}{(1+DCT)q_k}\left(YI_y - P_S S_y\right), \quad \text{for } k = 1, 2, \ldots, 49. \tag{16}$$

Substituting equation (16) into the objective function gives:

$$\overline{C}_y = \prod_{k=1}^{49}\left[\frac{\lambda_{ky}}{(1+DCT)q_k}\left(YI_y - P_S S_y\right)\right]^{\lambda_{ky}}. \tag{17}$$

Solving equation for YI_y - $P_S S_y$ yields:

$$YI_y - P_S S_y = \prod_{k=1}^{49}\left[\frac{(1+DCT)q_k}{\lambda_{ky}}\right]^{\lambda_{ky}} \overline{C}_y. \tag{18}$$

From equation (15), we have

$$YI_y - P_S S_y = \sum_{k=1}^{49}(1+DCT)q_k C_{ky} = \overline{q}_y \overline{C}_y. \tag{19}$$

Hence,

$$\overline{q}_y = \prod_{k=1}^{49}\left[\frac{(1+DCT)q_k}{\lambda_{ky}}\right]^{\lambda_{ky}}. \tag{20}$$

Ballard *et al*. (1985) treats household income as an exogenous variable because their model is static. In order for the whole model to have dynamic property, we explain household income as follows:

$$YI_y = YI\left[\sum_{j=1}^{206} w \cdot L_j, (1 + RGB_{-1})P_{S,-1}S_{y,-1}\right], \tag{21}$$

where w is the wage rate, L_j is employment in sector j, and RGB is the long-term interest rate. Among these three variables, the former two variables (w_t and L_{jt}) are explained in the input-output sub-model while the last variable (RGB) is determined in the financial sub-model. By endogenizing household income, household savings are determined as residuals.

Total commodity demand for age group y is explained by equation (9).[10] In order to apply equation (9), parameters α_y and σ_y must be given. Following Ichioka (1991, pp. 153-155), we discuss the calibration procedure of these parameters. Define the saving elasticity for age group y with respect to the real rate of return as:

$$\nu_y = \frac{\partial S_y}{\partial r}\frac{r}{S_y}, \tag{22}$$

where $r = P_K\zeta/P_S$. Assume that change in r is caused by that in ζ. Then, taking partial derivative of S_y with respect to r is sufficient to derive the first-term of equation (22). Since

$$\frac{\partial S_y}{\partial r} = \frac{\alpha_y(1-\alpha_y)(\sigma_y - 1)P_S{}^{\sigma_y}\bar{q}_y{}^{1-\sigma_y}r^{-\sigma_y}}{\Delta_y{}^2}, \tag{23}$$

we obtain, after some calculation, the following saving elasticity:

$$v_y = (\sigma_y - 1)\left(1 - \frac{P_S S_y}{YI_y}\right). \tag{24}$$

Solving equation (24) for σ_y gives:

$$\sigma_y = 1 + \frac{v_y}{1 - P_S S_y / YI_y}. \tag{25}$$

As for the derivation of α_y, we take the ratio of equation (9) to equation (11) as:

$$\frac{\bar{C}_y}{S_y} = \left(\frac{\alpha_y}{1-\alpha_y}\right)\left(\frac{P_S}{P_{Fy}}\right)\left(\frac{P_{Fy}}{\bar{q}_y}\right)^{\sigma_y}. \tag{26}$$

Rearranging equation (26) yields α_y as:

$$\alpha_y = \frac{\overline{C}_y}{\overline{C}_y + \left(P_S S_y / P_{Fy}\right)\left(P_{Fy} / \overline{q}_y\right)^{\sigma_y}} . \tag{27}$$

Once parameters σ_y and α_y are determined by equations (25) and (27) respectively, we can obtain the optimal composite good demand for age group y as in equation (9).

Then, we discuss the determination of commodity price and the structure of the commodity demand model follows. Although commodity price is given in a commodity demand model, it becomes one of the linkage variables between the household and input-output sub-models and is explained by sectoral price as:

$$q_k = q_k\left(P_i\right), \qquad k = 1, 2, \ldots, 49; i = 1, 2, \ldots, 206 \tag{28}$$

where P_i is price in sector i. The general commodity price is determined by the weighted average of age-grouped price for composite goods; i.e.,

$$P_{TL} = P_{TL}\left[\sum_y \left(\frac{NHH_y}{\sum_y NHH_y}\right)\overline{q}_y\right], \tag{29}$$

where P_{TL} is the average commodity price and NHH_y is the number of households for age group y.[11]

Household income and total commodity demand are estimated for each age group. As for age group 30-34, the following equations are estimated:

$$YI_{3034} = c_{11} + c_{12}\sum_{j=1}^{206} w \cdot L_j + c_{13}\left(1 + RGB_{-1}\right)P_{S,-1}S_{y,-1} + c_{14}D9095, \tag{30}$$

$$C_{3034} = c_{21} + c_{22}YI_{3034} + c_{23}D8287 + c_{24}D96LATER, \tag{31}$$

where *D*xxyy is a dummy variable which take 1 between 19xx and19yy; 0 otherwise and *D96LATER* is also a dummy variable which has 1 after 1996; 0 otherwise.

<Tables 1 and 2 around here>

2.2.2. Portfolio Selection

Household savings ($P_S S_y$) which are explained in the previous sub-section are further sub-divided as:

$$P_S S_y = P_{S1}S1_y + P_{S2}S2_y, \tag{32}$$

where $S1_y$ is asset which partially consists of the money supply (M2+CD) and $S2_y$ is the others. The allocation of total saving is determined by a portfolio selection model.[12] There is also an extensive literature on a portfolio selection model. In this model, we adopt a linear asset demand model developed by Friedman and Roley (1979) and Friedman (1985).[13][14] Friedman (1985) and Noland (1988) apply this model to data of the U.S. and Japan, respectively.

A. Case for Risky Assets Only

In order to allocate its aggregate asset, a household solves the following expected utility maximization problem:

$$\begin{aligned} &\max E\left[V\left(P_{S,+1}S_{y,+1}\right)\right] \\ &\text{s.t. } \mathbf{i}^{\mathrm{T}}\boldsymbol{\omega} = 1, \end{aligned} \tag{33}$$

where E is the expectation operator, $V(\cdot)$ is a constant relative risk aversion (CRRA) utility function, $\boldsymbol{\omega}$ is a vector of share of composite assets, $\mathbf{i}$ is a vector of ones, $\mathbf{i}^{\mathrm{T}}$ is transpose of $\mathbf{i}$. The evolving path of $P_{S,+1}S_{y,+1}$ is given by:

$$P_{S,+1}S_{y,+1} = P_S S_y \cdot \boldsymbol{\omega}^{\mathrm{T}}\left(\mathbf{i} + \mathbf{r}\right), \tag{34}$$

where $\mathbf{r}$ is a vector of the real return of each financial asset and is assumed to follow the following joint normal distribution:

$$\mathbf{r} \sim N\left(\mathbf{r}^{e}, \mathbf{\Omega}\right), \tag{35}$$

where $\mathbf{r}^e$ is a vector of the expected real return and $\mathbf{\Omega}$ is the variance-covariance matrix.

Taking expectation of the utility function after applying the Taylor series expansion to $V(P_{S,+1}S_{y,+1})$ around $E(P_{S,+1}S_{y,+1})$ up to the second degree yields:

$$E\left[V\left(P_{S,+1}S_{y,+1}\right)\right] = V\left[E\left(P_{S,+1}S_{y,+1}\right)\right] + \frac{1}{2}V''\left[E\left(P_{S,+1}S_{y,+1}\right)\right]\left(P_S S_y\right)^2 \boldsymbol{\omega}^{\mathrm{T}}\mathbf{\Omega}\boldsymbol{\omega}\,, \tag{36}$$

where $V''(\cdot)$ is the second derivative of $V(\cdot)$.

Then, the household solves the following Lagrangian:

$$Z_y = V\left[E\left(P_{S,+1}S_{y,+1}\right)\right] + \frac{1}{2}V''\left[E\left(P_{S,+1}S_{y,+1}\right)\right]\left(P_S S_y\right)^2 \boldsymbol{\omega}^{\mathrm{T}}\mathbf{\Omega}\boldsymbol{\omega} + \psi_y\left(1 - \mathbf{i}^{\mathrm{T}}\boldsymbol{\omega}\right), \tag{37}$$

where ψ_y is the Lagrange multiplier. The first-order conditions are:

$$\begin{aligned}\frac{\partial Z_y}{\partial \boldsymbol{\omega}} &= V'\left[E\left(P_{S,+1}S_{y,+1}\right)\right]E\left[\left(P_S S_y\right)\left(1 + \mathbf{r}^{e}\right)\right] \\ &\quad + V'\left[E\left(P_{S,+1}S_{y,+1}\right)\right]\left(P_S S_y\right)^2 \mathbf{\Omega}\boldsymbol{\omega} - \psi_y \mathbf{i}\end{aligned}, \tag{38}$$

$$\frac{\partial Z_y}{\partial \psi_y} = 1 - \mathbf{i}^{\mathrm{T}}\boldsymbol{\omega}\,, \tag{39}$$

where $V'(\cdot)$ is the first derivative of $V(\cdot)$. Setting equations (38) and (39) to zero and combining the results, we obtain the optimal portfolio selection as:

$$\boldsymbol{\omega} = \kappa_y \left(\boldsymbol{\Omega}^{-1} - \frac{\boldsymbol{\Omega}^{-1}\mathbf{i}\mathbf{i}^{\mathrm{T}}\boldsymbol{\Omega}^{-1}}{\mathbf{i}^{\mathrm{T}}\boldsymbol{\Omega}^{-1}\mathbf{i}} \right)\left(\mathbf{i} + \mathbf{r}^{e}\right) + \frac{\boldsymbol{\Omega}^{-1}\mathbf{i}}{\mathbf{i}^{\mathrm{T}}\boldsymbol{\Omega}^{-1}\mathbf{i}}\,. \tag{40}$$

where $\kappa_y = -V'\left(E\left[P_{S,+1}S_{y,+1}\right]\right) / \left[V''\left(E\left[P_{S,+1}S_{y,+1}\right]\right)\left(P_S S_y\right)\right]$.

B. Case for Including Risk-Free Asset

When risk-free asset is included, equation (40) is not the optimal solution.[15] Assume that the household does not have borrowing restrictions of risk-free asset. Then, the household will solve an unconstrained expected utility maximization problem. The optimal solution for risky asset is given by:

$$\tilde{\boldsymbol{\omega}} = \kappa_y \tilde{\boldsymbol{\Omega}}^{-1}\left(\mathbf{i} + \tilde{\mathbf{r}}^{e} - r^{f}\mathbf{i}\right) \tag{41}$$

where tilde refers to variables for risky assets and r^f is the real return of risk-free asset.

Since the composites of $S1_y$ are demand and time deposits, $S1_y$ can be interpreted as risk-free asset. Applying equation (41), we estimate the following equation by panel data technique:[16]

$$\begin{aligned}\frac{P_{S2}S2_y}{P_S S_y} &= c_{31}\left(\frac{YI_y/P_{TL}}{P_S S_y/P_{TL}}\right) + c_{32_y}\left[\{RGB - \mathrm{pch}(P_{TL})\} - \{RS - \mathrm{pch}(P_{TL})\}\right] \\ &+ c_{33_y} D8790 + c_{34_y} D98LATER\end{aligned} \quad . \tag{42}$$

where pch(x) is the rate of change in variable x, $D8790$ takes 1 for 1987-1990 and 0 otherwise, and $D98LATER$ takes 1 after 1998 and 0 otherwise. Here, we assume that the real return for risk-free and risky assets are represented by the short and long-term interest rates, respectively. Table 3 shows the estimation result for equation (42). Although several dummy variables are not statistically significant for certain age group, the overall results are sufficient.

<Table 3 around here>

2.3. Input-Output Sub-Model

The input-output sub-model fundamentally follows the Leontief input-output model; i.e., the summation of each intermediate demand and final demand equals total output. Differed from the Leontief model, our input-output sub-model determines sectoral price simultaneously. Therefore, consistent results for sectoral output and price can be obtained. Using price-linked 206-sector input-output tables for 1973-1999 complied by the Society of Dynamic Multi-Sectoral Econometric Modeling (2002), we estimate most parameters by econometric techniques.

2.3.1. The Wage Rate and Sectoral Price

In their model, McKibbin and Nguyen (2004) assume that labor is perfectly mobile among sectors; hence, the wage rate is common among sectors. We employ their approach to model labor market and modify their formulation of the wage rate determination. McKibbin and Nguyen (2004, p.47) formulate the wage rate equation as:

$$w_{+1} = w\left(\frac{PC^e_{+1}}{PC^e}\right)^{\alpha}\left(\frac{PC^e}{PC^e_{-1}}\right)^{1-\alpha}\left(\frac{L}{L^*}\right)^{\beta}, \tag{43}$$

where PC^e is expected price, L is employment, and L^* is full employment. In order to incorporate the effect of labor productivity on the wage rate, we modify equation (43) as:

$$w_{+1} = w_t\left(\frac{PC^e_{+1}}{PC^e}\right)^{\alpha}\left(\frac{PC^e}{PC^e_{-1}}\right)^{1-\alpha}\left(\frac{\sum_{j=1}^{206} L_j}{L^*}\right)^{\beta}\left(\frac{\sum_{j=1}^{206} XXR_j}{\sum_{j=1}^{206} L_j}\right)^{\gamma}, \tag{44}$$

where XXR_j is total output in sector j in constant price. After taking logarithms, we estimate the wage rate equation. Since the estimated parameter alpha exceeds one, the final version of the estimated equation (44) becomes as follows:

$$\ln\left(\frac{w_{+1}}{w}\right) = c_{41}\ln\left(\frac{P_{TL,+1}}{P_{TL}}\right) + c_{42}\ln\left(\frac{\sum_{j=1}^{206} L_j}{LF}\right) + c_{43}\ln\left(\frac{\sum_{j=1}^{206} XXR_j}{\sum_{j=1}^{206} L_j}\right) \\ + c_{44}D77 + c_{45}D80 + c_{46}D86 + c_{47}D91 + c_{48}D95 \tag{45}$$

where LF is labor force, $D77$, $D80$, $D86$, $D91$, and $D95$ take 1 for 1977, 1980, 1986, 1991, and 1995, respectively; 0 otherwise. The estimation result is shown in Table 4. In this estimation, the average commodity price and labor force are used as proxy variables for the expected price and full employment.

<Table 4 around here>

Following the cost structure of an input-output table, sectoral price is determined by adding cost of production. Among the cost factors, cost of intermediate inputs and wages are main ones. Thus, sectoral price is explained in our model as:

$$P_j = P_j\left(\frac{\sum_{i=1}^{206} P_i XR_{ij}}{XXR_j}, \frac{wL_j}{XXR_j}\right), \tag{46}$$

where P_j is price for sector j, XR_{ij} is input of good i in sector j in constant price.

The estimated equation for price in sector 92 (cement products) can be written as:

$$\ln P_{92} = c_{51} + c_{52} \ln\left(\frac{\sum_{i=1}^{206} P_i XR_{i,92}}{XXR_{92}} \right) + c_{53} \ln\left(\frac{wL_{92}}{XXR_{92}} \right). \tag{47}$$

Table 5 presents the fine result for the estimation of this equation.

<Table 5 around here>

2.3.2. Intermediate Input, Sectoral Employment, and Capital Stock

Regarding production technology, Ozaki (1979) and Ozaki, Kuroda, and Nomura (2000) emphasize the importance of economies of scale. Nakamura (1990) presents a generalized Leontief unit cost function which embodies economies of scale by enlarging Fuss (1977) and named it a generalized Ozaki unit cost function. In this paper, a representative firm of each sector is assumed to have a generalized Ozaki unit cost function with factor limitation assumption as a consequence of cost minimization given sectoral output. If we omit technological change, Nakamura's (1990) generalized Ozaki unit cost function with factor limitation assumption is given by:

$$UC_j = \sum_i a_{ij} XXR_j^{\ b_{ij}} P_i, \tag{48}$$

where UC_j is the unit cost in sector j and subscript i denotes input (each intermediate input, labor, and capital stock).[17] Additionally, we assume that intermediate input follows the Leontief formulation (*i.e.*, fixed proportions). Applying the Shephard's lemma and rearranging the results, we obtain the derived demand of each intermediate input, labor, and capital in sector j as:

$$XR_{ij} = a_{ij} XXR_j, \tag{49}$$

$$L_j = a_{Lj} XXR_j^{\ b_{Lj}+1}, \tag{50}$$

$$K_j = a_{Kj} XXR_j^{\ b_{Kj}+1}, \tag{51}$$

where a_{ij} is input coefficient, K_j is capital stock in sector j.[18] For equations (49), (50), and (51), superscript b_{qj} ($q = i$, L, and K) is a parameter which expresses the degree of economies of scale. If $b_{hj} < 0$, sector j exhibits economies of scale with respect to input h.

We present estimation result for labor demand in sector 116 (metal machinery) in Table 6. The estimated equation is:

$$\ln L_{116} = c_{61} + c_{62} \ln XXR_{116} + c_{63} D76 , \tag{52}$$

where $D76$ is a dummy variable which takes 1 for 1976 and 0 otherwise.

<Table 6 around here>

Since an input-output table has data on wages for each sector, we can compute sectoral employment given the common wage rate described in the previous sub-section calculated by using aggregate labor data. By contrast, an input-output table does not have data on capital stock except for depreciation. Therefore, we do not determine capital stock by equation (51). At aggregate level, we have an identity of value added with respect to distribution; i.e.,

$$PVA \sum_{j=1}^{206} VAR_j = w \sum_{j=1}^{206} L_j + P_K \sum_{j=1}^{206} K_j , \tag{53}$$

where PVA is price deflator for value added, VAR_j is value added in sector j in constant price, and P_K is the user cost of capital.[19] Based on the specification in Inada (1991), the user cost of capital is defined as:

$$P_K = \frac{PI(\delta + RGB)}{1 - HTAX}, \tag{54}$$

where PI is price deflator for aggregate investment, δ is the depreciation rate, and $HTAX$ is the corporate tax rate. Using equation (53), we obtain the aggregate capital stock as:

$$\sum_{j=1}^{206} K_j = \frac{(P_j / PVA)\sum_{j=1}^{206} XXR_j - \sum_{j=1}^{206} VAR_j - (w/PVA)\sum_{j=1}^{206} L_j}{(P_K / PVA)}. \tag{55}$$

2.3.3. Final Demand

Final demand is composed of non-household consumption expenditure, household consumption expenditure, the other private consumption expenditure, government consumption, private investment, government investment, inventories, export, and import.[20] For each final demand component, its total is determined first, and then it is allocated into demand for each sector.

A.Household Consumption Expenditure

Total household consumption expenditure is explained by total commodity demand. Since household's commodity demand is measured in monthly expenditure, it should be converted into annual and macro level data. To begin, the annual demand for commodity k in constant price for the entire sample can be defined as:

$$12\sum_{y} C_{ky} NHH_{y} \ . \tag{56}$$

Then, per capita annual demand for commodity k in constant price for the entire sample is given by:

$$\left(\frac{12}{NHH \cdot SNM}\right)\sum_{y} C_{ky} NHH_{y} \ , \tag{57}$$

where NHH is the number of sample households and SNM is the average number of people for the all samples. Therefore, the annual demand for commodity k in constant price at aggregate level ($C95_k$) is given by:

$$C_{k} = \left(\frac{12 \cdot N}{NHH \cdot SNM}\right)\sum_{y} C_{ky} NHH_{y} \ , \tag{58}$$

where N is total population. Using this result, total household consumption expenditure is explained as:

$$\sum_{i=1}^{206} CPR_{i} = CPR\left(\sum_{k=1}^{49} C_{k}\right), \tag{59}$$

where CPR_i is household consumption expenditure in sector i. Each sector's household consumption expenditure is determined by:

$$\frac{CPR_i}{\sum_{i=1}^{206} CPR_i} = S\_CPR_i^* \left(\frac{P_i}{PCP} \right)^{\eta_{CPR_i}}, \tag{60}$$

where $S\_CPR_i^*$ is the base share of good i, PCP is the price deflator for $\sum_{i=1}^{206} CPR_i$, and η_{CPRi} is elasticity of substitution.[21] Car industry's household consumption is estimated by using the following equation:

$$\ln\left(\frac{CPR_{136}}{\sum_{i=1}^{206} CPR_i} \right) = c_{71} + c_{72} \ln\left(\frac{P_{136}}{PCP} \right) + c_{73} \left(\frac{CPR_{136,-1}}{\sum_{i=1}^{206} CPR_{i,-1}} \right) + c_{74} D98, \tag{61}$$

where $D98$ takes 1 for 1998 and 0 otherwise, and subscript 136 indicates the sector number of car industry. The estimated result for equation (61) is shown in Table 7.

<Table 7 around here>

B.Private Investment

As for capital stock, we have the following identity:

$$K_{+1} = K + I - \delta K \,, \tag{62}$$

where K is the aggregate capital stock and I is the aggregate investment. Using this fact, the aggregate private investment is determined by:

$$\sum_{i=1}^{206} IFPR_i = IFPR\left[\sum_{j=1}^{206} K_{j,+1} - (1-\delta)\sum_{j=1}^{206} K_j\right], \tag{63}$$

where $IFPR_i$ is private investment in sector i. Equation (63) represents an internal linkage mechanism between capital stock determined by equation (55) and private investment. The allocation of total private investment takes the same approach for household consumption expenditure.

C. Import

Total import is explained as:

$$\sum_{i=1}^{206} IMR_i = IMR\left(\sum_{j=1}^{206} VAR_j, \frac{PVA}{PIM}\right), \tag{64}$$

where IMR_i is import in sector i in constant price and PIM is the price deflator for total import. The allocation mechanism among sectors is the same as household consumption expenditure's.

D. Non-Household, the Other Private, Government Consumption Expenditures, Government Investment, Inventories, and Export

Totals of these final demand components are exogenous and their shares are taken from the input-output tables.

2.3.4. Sectoral Output

Adding the intermediate demand and final demand over sector j give the total output in the sector i. Mathematically, this identity can be written as:

$$\begin{aligned} XXR_i = &\sum_{j=1}^{206} XR_{ij} + CPXR_i + CPR_i + CPOR_i + IFPR_i + IGR_i \\ &+ IVR_i + EXR_i - IMR_i + QXR_i, \end{aligned} \tag{65}$$

where $CPXR_i$ is the non-household consumption expenditure in sector i in constant price, $CPOR_i$ is the other private consumption expenditure in sector i in constant price, IGR_i is government investment in sector i in constant price, IVR_i is inventories in sector

i in constant price, EXR_i is export in sector i in constant price, and QXR_i is the statistical discrepancy in the sector i in constant price.

2.4. Financial Sub-Model

Financial sub-model explains the long-term interest rate through the money market equilibrium as well as the short-term interest rate.

Risk-free asset determined by household's portfolio selection consists of a portion of the money supply (M2+CD). Hence, we have:

$$MS = MS(S1), \tag{66}$$

where MS is the money supply and $S1$ is risk-free asset demand.[22] By contrast, the money demand is explained by:

$$\frac{MD}{PVA} = MD\left(\sum_{j=1}^{206} VAR_j, RGB\right), \tag{67}$$

where MD is the money demand. As an equilibrium condition in the money market, we also have:

$$MD = MS. \tag{68}$$

From equations (66), (67), and (68), the long-term interest rate is determined. The equation for the short-term interest rate is expressed as:

$$RS = RS(RMM), \tag{69}$$

where RS is the short-term interest rate and RMM is the call rate.

We demonstrate the estimation result for the long-term interest rate in Table 8. The estimated equation is given by:

$$\begin{aligned} RGB = {} & c_{81}\left(\frac{MS}{PVA}\right) + c_{82}\sum_{j=1}^{206} VAR_j + c_{83} RGBUSA \\ & + c_{84} RS + c_{85} D8990 + c_{86} D99 \end{aligned} \tag{70}$$

where $D8990$ takes 1 between 1989 and 1990; 0 otherwise, $D99$ takes 1 in 1999; 0 otherwise, and $RGBUSA$ is the long-term interest rate of the United States.

<Table 8 around here>

2.5. Population Sub-Model

The population sub-model determines the number of households for age group y of household heads, the average number of people in a household, and population for age group *y*.[23]

Assuming that demographic structure affects the number of households for age group *y*, we formulate its equation as:

$$\left(\frac{NHH_y}{NHH}\right) = NHH_y\left(\frac{N_y}{N}\right), \tag{71}$$

where N_y is population for age group *y*.

Observing the hump shape of the number of people in a household with respect to age group *y*, we explain it by applying Fair and Dominguez's (1991) approach to include the demographic structure effects on consumption as:

$$\begin{aligned} SNM &= c_{91} + c_{92}\left[\sum_{v=1}^{10} v \cdot pop_v - \left(\frac{1}{10}\right)\sum_{v=1}^{10} v \sum_{v=1}^{10} pop_v\right] \\ &\quad + c_{93}\left[\sum_{v=1}^{10} v^2 \cdot pop_v - \left(\frac{1}{10}\right)\sum_{v=1}^{10} v^2 \sum_{v=1}^{10} pop_v\right], \end{aligned} \tag{72}$$

where *v* is the ordered index number of age group *y* and pop_v is the share of population indexed by *v*.[24]

Regarding population for age group *y*, we apply the following simple equation for its explanation:

$$N_y = N_y\left(N_{y,-1}, N\right). \tag{73}$$

3. Final Test and Simulations

3.1. Final Test

In order to evaluate its tractability, the model is solved from 1994 to 1998.[25] The mean absolute percentage errors (MAPE) for selected variables are shown in Table 9. Although the long-term interest rate should be improved, the overall results are sufficient.

<Table 9 around here>

3.2. Case A: Population Decrease

Among possible demographic change, this paper focuses on population decrease. The National Institute of Population and Social Security Research provides three population projection: high, medium, and low variants. The medium variant is used to the baseline. Regarding this simulation, we employ the low variant from 2005 to 2015 and quantify multi-sectoral effects of further population decrease from the baseline. For the other exogenous variables, the past growth rates are applied to forecast those variables with trend and the latest values for those without trend.

Table 10 presents average of percent deviations of selected commodity demands for each age-group.[26] Demands would decrease for all commodities and age groups (in exception to foot wear of age groups under 24, 45-49, 50-54, and 60-64). Absolute values of the percent deviations would be similar among age groups. Although commodities on clothing and housing would not decrease so much, those on education and public utilities would relatively decrease.

<Table 10 around here>

Table 11 shows percent deviations of before-tax commodity prices from the baseline. Prices would go up for all commodities. Prices for education and public utilities would rise in particular; while those for clothing and housing would not rise. On the whole, the inverse patter of commodity demands emerged in commodity prices.

<Table 11 around here>

Table 12 illustrates percent deviations of total output from the baseline. Basically, total output would decrease: however, that would increase in 44 sectors out of 206 sectors. Precision machine would increase, in particular. By contrast, many service and public utility sectors would have decrease in total output. Since absolute values of percent deviations are increasing as time passes, the effects of population decrease are getting bigger with time.

<Table 12 around here>

Table 13 shows percent deviations of sectoral price from the baseline. Although price would decrease in some sectors, that would increase in most sectors. We can observe rough inverse relationship between total output and sectoral price. Particularly, prices for service and public utility sectors would increase. As with the case of total output, the degree of effects of population decrease on sectoral price would become greater as time goes.

<Table 13 around here>

3.3. Case B: Increase in the Consumption Tax Rate

One of the hot issues in terms of fiscal policy is possible change in the consumption tax rate. The Government of Japan has huge amount of fiscal debt due to massive public investment during the post-bubble period. In addition, it is said that the government debt can be increased since aging causes for the shortage of public pension funds. Currently, the increase in the consumption tax rate is focused as one of the measures to decrease fiscal debt. Observing this fact, we simulate the effects of the consumption tax rate increase on commodity demand and industrial structures until 2015. In this simulation, the consumption tax rate is set to 7.5 percent from 2008 to 2009 and 10 percent from 2010 to 2015. As for the population projection, we use the medium variant projected by the National Institute of Population and Social Security Research.

Table 14 demonstrates average of percent deviations of selected commodity demands for each age-group. Due to the rise in the consumption tax rate, demands (in average) for all twenty commodities would go down. Particularly, demands for communication, water supply, and other heating and lighting would be greatly decreased. By contrast, the effects on demands for foot wear, textile, and miscellaneous expenditure would be relatively smaller. Basically, the commodities in the first ten groups are related to clothing and housing while those for the last ten group are related to public utilities and foods. According to these results, households would react to decrease their expenditure of daily necessities against the increase of the consumption tax rate. Besides, the average change with respect to age-group differs for each other. The changes in age-groups of 25-29, 35-39, and 40-44 would be smaller than those in age-groups of under 24, 60-64, and over 65. The number of people in a household and income levels might be the causes for the difference. The further investigations on this topic would be necessary.

<Table 14 around here>

The results for the first and last ten before-tax commodity prices in terms of average changes are presented in Table 15. Prices for the twenty commodities would increase in both 2008 and 2010. For 2015, the last nine commodities would become cheaper than the baseline. The results show that change in the consumption tax rate particularly would affect price for communication and water supply. Prices for many public utilities (transportation, other heating and lighting, and electricity) and education are included in the first ten commodity group. On the contrary, prices for foods (vegetables, cereals, and fruits), clothing (other clothing and clothing related service), and housing (housing facility and its maintenance, interior decoration, and rent) are mainly contained in the last ten commodity group. Since the largest decrease of the price change would be 2 percent in absolute value, after-tax commodity price would go up for all commodities from 2008 to 2015.

<Table 15 around here>

Percent deviations of selected sectors' output are presented in Table 16. We find that outputs for the aircraft and its repair (over 15 percent), and processed agricultural product (over 7 percent) sectors would increase while those for communication (less than -11 percent) and civilian-use electric apparatus (less than -10 percent) sectors would decrease. Of 206 sectors, we found output increase in 50 sectors. Although the changes in differ in terms of sectors, output at aggregate level would decrease.

<Table 16 around here>

Table 17 shows the changes in selected sectors' prices. Similar to the result in commodity price, the price for the communication sector would increase, in particular. Prices for the barley and cereal sector, life insurance sector and public utilities (communication, and electricity) would go up while those for sectors related to non-residential construction, aircraft and its maintenance, and foods (paddy and fruits) would go down. Among 206 sectors, prices for 19 sectors would decline. Compared to commodity price, the larger range of percent deviations is found for sectoral prices.

<Table 17 around here>

4. Conclusions

Demographic change is one of the important policy issues for developed countries. In particular, Japan has been experiencing the rapid population decrease and aging. Demographic change as well as enormous amount of public investment during the 1990s cause for huge fiscal debt in Japan. The debt further causes for future uncertainty.

In this paper, we constructed a 206-sector price-linked input-output model with a detailed household commodity demand sub-model and financial sub-model for the Japanese economy. Applying the model, we analyzed the effects of population decrease and the increase in the consumption tax rate on commodity demand and industrial structures. As a result, the followings are found for both simulation scenarios:

- All commodity demands would be decreased. Among commodities, decreases in demands for clothing would be small while those in foods and public utilities would be large. The effects differ for each age-group. For both simulation scenarios, before-tax as well as after-tax commodity prices would increase. The effects on public utilities and services are particularly large. By contrast, the effects on prices for foods, clothes, and housing would be limited.
- Sectoral output would essentially decrease. Particularly, outputs for the public

utility and food sectors would go down. On the contrary, sectoral price would basically go up. Prices for public utility and service sectors would increase, in particular.

According to the final test result, the performance of the model is essentially acceptable. However, several formulations must/can be improved. First, the population sub-model must be estimated econometrically in order to explain aging endogenously. Second, although most computable general equilibrium models ignore the dynamics of these parameters, they vary by time and age. The dynamics of parameter lambdas (powers in composite goods) must be described empirically as well. Finally, input coefficients also vary by time. These parameters can be treated endogenously by applying the framework of Nakamura (1990). These issues can be future research topics in order to improve the performance of the model.

Notes

[1] According to Horioka (forthcoming), the private investment is the most responsible to the so-called "Lost Decade."
[2] McKibbin and Nguyen (2004) is based on the McKibbin-Sachs Global (MSG) model version 3 whereas Faruqee and Mühleisen (2003) and Shi and Tyres (2005) add a demographic block to the International Monetary Fund's MULTIMOD model and a dynamic version of the Global Trade Analysis Project (GTAP) model, respectively. Although Faruqee and Mühleisen's (2003) model deals with macro economy, the models of McKibbin and Nguyen (2004) and Shi and Tyres (2005) are multi-sectoral.
[3] A similar system is proposed in Wakabayashi (2002).
[4] All variables used below are at time *t* unless time is indicated.
[5] For Geary's discussion, see Geary (1950-51).
[6] The model in Ballard et al. (1985) is one of the benchmark models in computable general equilibrium modeling. For instance, Ichioka (1991) is an application of Ballard et al. (1985) to Japan's economy.
[7] Ballard et al. (1985) accounts for labor-leisure decision in the same framework. However, our model explains labor demand by a different approach. Thus, labor-leisure decision is omitted in

our formulation.

[8] Due to the property of the Cobb-Douglas function, $\sum_{k=1}^{49} \lambda_{ky} = 1$.

[9] The expected price for the future good is assumed to equal the price for the composite good.

[10] Alternatively, total commodity demand for age group y is simply explained by its income in this paper. Estimated equation is equation (31) and its result is presented in Table 2.

[11] The weights are computed by using the number of households for each age group because commodity demands per household are provided.

[12] In this model, $S1_y$ contains neither cash nor derivative deposit. Hence, $S1_y$ becomes a fraction of the money supply.

[13] The derivations in this sub-section heavily drawn from Friedman and Roley (1979) and Friedman (1985).

[14] Another approach to explain household portfolio selection is a life-time portfolio model developed by Merton (1969) and Samuelson (1969). In their model, asset allocation and commodity demand are determined simultaneously. Differed from this approach, we assume that households determine their asset allocation after the determination of their commodity demands.

[15] In this paper, risk-free asset represents demand and time deposits

[16] The first term of equation (42) is included to account for payment measure of money. This specification follows Friedman (1985).

[17] Originally, Nakamura (1990) includes time trend which represents technological change in the generalized Ozaki unit cost function.

[18] Since the defined cost function (equation 48) is a unit cost function, one is added to the parameter of economies of scale in equations (50) and (51).

[19] A similar identity is employed in Tokutsu (1994).

[20] All components are in constant price.

[21] This formulation follows Kosaka (1994).

[22] It is noted that for computation of $S1$, similar steps to computation of $C95_k$ is necessary due to the unit of data.

[23] Final test results showed that inclusion of estimated population sub-model caused for collapse of the whole model. Thus, all variables of the population sub-model are treated as exogenous. In this paper, we present a possible theoretical framework for the population sub-model.

[24] A detailed derivation of demographic-structure variables is provided in Fair and Dominguez (1991, p. 1280).

[25] Due to data limitation and the forward looking formulation in the total investment equation, the model can solve properly from 1994 to 1998.

[26] Tables 10 and 11 contain the first and last ten commodities or sectors with respect to average changes.

References

Almon, Clopper. 1996. "A Perhaps Adequate Demand System." INFORUM Working Paper Series, no. 96-007. College Park, Md.: Interindustry Forecasting at the University of Maryland. (Available at http://inforumweb.umd.edu/Workpaper/INFORUM/wp96007.pdf)

Asano, Seki. 1997. "Joint Allocation of Leisure and Consumption Commodities: A Japanese Extended Consumer Demand System 1979-90." *Japanese Economic Review* 48, no. 1: 65-80.

Ballard, Charles L.; Don Fullerton; John B. Shoven; and John Whalley. 1985. *A*

General Equilibrium Model for Tax Policy Evaluation. Chicago: University of Chicago Press.

Christensen, Laurits R.; Dale W. Jorgenson; and Lawrence J. Lau. 1975. "Transcendental Logarithmic Utility Functions." *American Economic Review* 65, no. 3: 367-83.

Deaton, Angus, and John Muellbauer. 1980. "An Almost Ideal Demand System." *American Economic Review* 70, no. 3: 312-26.

Fair, Ray C., and Kathryn M. Dominguez. 1991. "Effects of the Changing U.S. Age Distribution on Macroeconomic Equations." *American Economic Review* 81, no. 5: 1276-94.

Faruqee, Hamid, and Martin Mühleisen. 2003. "Population Aging in Japan: Demographic Shock and Fiscal Sustainability." *Japan and the World Economy* 15, no. 2: 185-210.

Friedman, Benjamin M. 1985. "The Substitutability of Debt and Equity Securities." In *Corporate Capital Structure in the United States*, ed. Benjamin M. Friedman. Chicago: University of Chicago Press.

Friedman, Benjamin M., and V. Vance Roley. 1979. "A Note on the Derivation of Linear Homogeneous Asset Demand Functions." NBER Working Paper Series, no. 345. Cambridge, Mass.: National Bureau of Economic Research.

Fuss, Melvyn A. 1977. "The Structure of Technology Over Time: A Model for Testing the 'Putty-Clay' Hypothesis." *Econometrica* 45, no. 8: 1797-1821.

Geary, R. C. 1950-51. "A Note on 'A Constant-Utility Index of the Cost of Living.'" *Review of Economic Studies* 18, no. 1: 65-6.

Horioka, Charles Yuji. forthcoming. "The Causes of Japan's 'Lost Decade': The Role of Household Consumption." *Japan and the World Economy*.

Ichioka, Osamu. 1991. *Ōyō ippan kinkō bunseki* [Applied general equilibrium analysis]. Tokyo: Yuhikaku.

Inada, Yoshihisa. 1991. *Nichibei keizai no sōgo izon to rinku moderu* [Economic interdependency between Japan and the U.S. and multi-country modeling]. Tokyo: Nippon Hyoron-Sha.

Klein, L. R., and H. Rubin. 1947-48. "A Constant-Utility Index of the Cost of Living." *Review of Economic Studies* 15, no. 2: 84-7.

Koga, Maiko. 2005. "The Decline of Japan's Saving Rate and Demographic Effects." Bank of Japan Working Paper Series, no. 05-E-10. Tokyo: Bank of Japan.

Kosaka, Hiroyuki. 1994. *Gurōbaru shisutemu no moderu bunseki* [Model analysis on global system]. Tokyo: Yuhikaku.

McKibbin, Warwick J., and Jeremy Nguyen. 2004. "Modeling Global Demographic Change: Results for Japan." Unpublished Manuscript. (Available at http://www.sensiblepolicy.com/download/M&Ndemographics.pdf)

Merton, Robert C. 1969. "Lifetime Portfolio Selection under Uncertainty: The Continuous-Time Case." *Review of Economics and Statistics* 51, no. 3: 247-257.

Murata, Keiko. 2003. "Precautionary Savings and Income Uncertainty: Evidence from Japanese Micro Data." *Monetary and Economic Studies* 21, no. 3: 21-52.

Nakamura, Shinichiro. 1990. "A Nonhomothetic Generalized Leontief Cost Function Based on Pooled Data." *Review of Economics and Statistics* 72, no. 4: 649-56.

Okamoto, Akira. 2005. "Simulating Fundamental Tax Reforms in an Aging Japan." *Economic Systems Research* 17, no. 2: 163-85.

Ozaki, Iwao. 1979. "Keizai hatten no kōzō bunseki I: Kōzō henka wo fukumu Leontief dōgaku taikei" [The structure of economic development]. *Mita gakkai zasshi* 72, no. 6: 84-112.

Ozaki, Iwao; Masahiro Kuroda; and Koji Nomura. 2000. "Economies of Plant-Scale and Structural Change." Paper presented at the Thirteenth International Conference on Input-Output Techniques. Macerata, Italy. August.

Samuelson, Paul A. 1969. "Lifetime Portfolio Selection by Dynamic Stochastic Programming." *Review of Economics and Statistics* 51, no. 3: 239-246.

Sasaki, Kozo. 1996. "Consumer Demand in Japan: An Analysis Using the Deaton-Muellbauer System." *Japan and the World Economy* 8, no. 3: 335-51.

Shi, Qun, and Rod Tyers. 2005. "Global Demographic Change and Economic Performance: Applications of an Augmented GTAP-Dynamic." College of Business and Economics Working Papers in Economics and Econometrics no. 450. Canberra: Australian National University.

Society of Dynamic Multi-Sectoral Econometric Modeling, ed. 2002. *Sangyō renkan gata dōgaku teki keiryō moderu ni yoru chūchōki keizai yosoku ni kansuru chōsa kenkyū* [Research in the mid and long-term economic forecasting by using a dynamic multi-sectoral econometric model]. Tokyo: Japan Industrial Policy Research Institute.

Stone, Richard. 1954. "Linear Expenditure Systems and Demand Analysis: An Application to the Pattern of British Demand." *Economic Journal* 64, no. 255: 511-27.

Tokutsu, Ichiro. 1994. *Seisan kōzō no keiryō bunseki* [Econometric Analyses on Production Structure]. Tokyo: Sobunsha.

Usami, Maki; Takatoshi Tomoyose; and Hiroyuki Kosaka. 2004. "Jinkō kōzō to sangyō kōzō no henka" [Aging and its influence on the change of sectoral structure]. Paper presented at the Fifteenth Conference of the Pan Pacific Association of Input-Output Studies. Kusatsu, Japan. October.

Wakabayashi, Masayo. 2001. "Kakei shōhi senkō no raifu saikuru henka" [Household's preference related with its life cycle profile]. *Denryoku keizai kenkyū* 45: 17-34.

Wakabayashi, Masayo. 2002. "Kōreika no eikyō wo orikonda shōhi moderu no kaihatsu" [Estimation of an AIDS-type consumption model with age effets]. *Denryoku keizai kenkyū* 48: 45-54.

Appendix

The appendix shows data sources except for variables obtained by computation.

Variables: C_{ky}, q_k, P_{TL}, YI_y, S_y, $S1_y$, $S2_y$, NHH, NHH_y, SNM

Source: Statistics Bureau, Management and Coordination Agency, the Government of Japan, *Annual Report on the Family Income and Expenditure Survey*.

Variables: MS, RMM, RS, RGB, $RGBUSA$

Source: International Monetary Fund (IMF), *International Financial Statistics*.

Variables: L, LF

Source: Organisation for Cooperation and Development (OECD), *Labour Force Statistics*.

Variables: XR_{ij}, XXR_{ij}, CPR_i, $CPOR_i$, $CPXR_i$, CGR_i, $IFPR_i$, IGR_i, IVR_i, EXR_i, IMR_i, QXR_i

Source: Society of Dynamic Multi-Sectoral Econometric Modeling (2002)

Variables: N and N_y

Source: Statistics Bureau, Management and Coordination Agency, the Government of Japan, *Population Estimates*

Variables: *HTAX*

Source: Ministry of Finance, Finance and Money Statistics Monthly

Table 1: Estimation Result for Household Income Equation: Age Group 30-34

Parameter	Coefficient	S.E.	P-Value
c_{11}	197287.279	32550.970	0.000
c_{12}	0.001	0.000	0.003
c_{13}	0.443	0.169	0.016
c_{14}	101000.298	31742.157	0.004
Adjusted R^2	0.830		
S.E.	46635.707		
D.W.	1.023		
Sample	1973-1999		

Table 2: Estimation Result for Total Commodity Demand Equation: Age Group 30-34

Parameter	Coefficient	S.E.	P-Value
c_{21}	2.444	0.482	0.000
c_{22}	0.763	0.038	0.000
c_{23}	0.107	0.029	0.001
c_{24}	0.293	0.034	0.000
Adjusted R^2	0.950		
S.E.	0.062		
D.W.	2.081		
Sample	1973-1999		

Table 3: Estimation Result for Asset Demand Equation

Parameter	Coefficient	S.E.	P-Value
c_{31}	-0.996	0.016	0.000
c_{32}_24	0.706	0.042	0.000
c_{32}_2529	0.694	0.055	0.000
c_{32}_3034	0.806	0.032	0.000
c_{32}_3539	0.847	0.026	0.000
c_{32}_4044	0.833	0.027	0.000
c_{32}_4549	0.787	0.016	0.000
c_{32}_5054	0.761	0.013	0.000
c_{32}_5559	0.717	0.010	0.000
c_{32}_6064	0.695	0.008	0.000
c_{32}_65	0.696	0.009	0.000
c_{33}_24	-0.035	0.105	0.737
c_{33}_2529	0.083	0.133	0.535
c_{33}_3034	0.029	0.077	0.708
c_{33}_3539	-0.001	0.063	0.983
c_{33}_4044	0.157	0.064	0.015
c_{33}_4549	0.009	0.038	0.809
c_{33}_5054	0.036	0.031	0.251
c_{33}_5559	0.080	0.024	0.001
c_{33}_6064	0.013	0.020	0.503
c_{33}_65	0.104	0.022	0.000
c_{34}_24	-0.319	0.135	0.019
c_{34}_2529	0.553	0.179	0.002
c_{34}_3034	0.565	0.104	0.000
c_{34}_3539	1.451	0.085	0.000
c_{34}_4044	0.570	0.086	0.000
c_{34}_4549	0.259	0.051	0.000
c_{34}_5054	0.117	0.042	0.005
c_{34}_5559	0.142	0.033	0.000
c_{34}_6064	0.005	0.027	0.862
c_{34}_65	0.012	0.029	0.672
Adjusted R^2	0.935		
S.E.	0.131		
Sample	1973-1999		

Note: Two or four digit number on parameters denotes age group of household head.

Table 4: Estimation Result for the Wage Rate Equation

Parameter	Coefficient	S.E.	P-Value
c_{41}	0.940	0.084	0.000
c_{42}	1.219	0.659	0.081
c_{43}	0.005	0.002	0.016
c_{44}	0.063	0.014	0.000
c_{45}	-0.103	0.014	0.000
c_{46}	0.049	0.014	0.003
c_{47}	0.041	0.014	0.011
c_{48}	-0.051	0.014	0.002
Adjusted R^2	0.944		
S.E.	0.014		
D.W.	1.343		
Sample	1973-1999		

Table 5: Estimation Result for Sectoral Price Equation: Cement Product Sector

Parameter	Coefficient	S.E.	*P*-Value
c_{51}	0.833	0.015	0.000
c_{52}	0.647	0.023	0.000
c_{53}	0.333	0.013	0.000
Adjusted R^2	0.997		
S.E.	0.015		
D.W.	1.360		
Sample	1973-1999		

Table 6: Estimation Result for Labor Demand: Metal Machinery Sector

Parameter	Coefficient	S.E.	P-Value
c_{61}	6.255	0.746	0.000
c_{62}	0.375	0.053	0.000
c_{63}	-0.476	0.120	0.001
Adjusted R^2	0.788		
S.E.	0.110		
D.W.	1.022		
Sample	1973-1999		

Table 7: Estimation Result for Household Consumption Expenditure: Car Sector

Parameter	Coefficient	S.E.	P-Value
c_{71}	-1.121	0.317	0.002
c_{72}	-0.599	0.167	0.002
c_{73}	0.712	0.077	0.000
c_{74}	-0.275	0.083	0.003
Adjusted R^2	0.966		
S.E.	0.079		
D.W.	2.045		
Sample	1973-1999		

Table 8: Estimation Result for the Long-Term Interest Rate

Parameter	Coefficient	S.E.	P-Value
c_{81}	-0.017	0.004	0.001
c_{82}	0.000	0.000	0.002
c_{83}	0.158	0.046	0.002
c_{84}	1.169	0.091	0.000
c_{84}	1.438	0.380	0.001
c_{85}	1.660	0.549	0.006
Adjusted R^2	0.969		
S.E.	0.444		
D.W.	1.410		
Sample	1973-1999		

Table 9: Mean Absolute Percentage Errors for Selected Variables

	MAPE
$\sum_{k=1}^{49} C_k$	2.415
$\sum_{j=1}^{206} K_j$	2.968
$\sum_{j=1}^{206} L_j$	1.140
MS	2.604
P_{TL}	3.163
RGB	22.720
$S2$	3.156
w	3.229
$\sum_{i=1}^{206} XXR_i$	2.534

Table 10: Mean of Percent Deviation of Selected Commodity Demand for Each Age-Group from the Baseline (Case A)

Commodity	Age Group									
	Under 24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	Over 65
Foot wear	0.053	-0.040	-0.044	-0.027	-0.015	0.020	0.027	-0.012	0.022	-0.001
Other clothing	-0.234	-0.327	-0.331	-0.314	-0.302	-0.267	-0.260	-0.299	-0.265	-0.288
Rent	-0.236	-0.329	-0.333	-0.316	-0.305	-0.269	-0.263	-0.301	-0.268	-0.290
Shirt and sweater	-0.413	-0.505	-0.509	-0.492	-0.480	-0.445	-0.439	-0.477	-0.444	-0.466
Clothing related service	-0.426	-0.519	-0.523	-0.506	-0.494	-0.459	-0.452	-0.490	-0.457	-0.480
Medical service	-0.427	-0.519	-0.523	-0.506	-0.495	-0.459	-0.453	-0.491	-0.458	-0.481
Texture	-0.441	-0.534	-0.538	-0.521	-0.509	-0.474	-0.467	-0.505	-0.472	-0.495
Housing facility and its maintenance	-0.507	-0.599	-0.603	-0.586	-0.574	-0.539	-0.533	-0.571	-0.538	-0.560
Books	-0.507	-0.599	-0.603	-0.586	-0.575	-0.539	-0.533	-0.571	-0.538	-0.561
Amusement durables	-0.533	-0.626	-0.630	-0.613	-0.601	-0.566	-0.559	-0.597	-0.564	-0.587
Medical equipment	-1.045	-1.136	-1.140	-1.123	-1.112	-1.077	-1.071	-1.108	-1.076	-1.098
Amusement service	-1.046	-1.138	-1.142	-1.125	-1.113	-1.078	-1.072	-1.110	-1.077	-1.099
Transportation	-1.054	-1.145	-1.149	-1.132	-1.121	-1.086	-1.080	-1.117	-1.085	-1.107
Cooked food	-1.177	-1.268	-1.272	-1.256	-1.244	-1.209	-1.203	-1.241	-1.208	-1.230
Household durable goods	-1.360	-1.451	-1.455	-1.438	-1.427	-1.392	-1.386	-1.423	-1.391	-1.413
Other heating and lighting	-1.447	-1.538	-1.542	-1.525	-1.514	-1.479	-1.473	-1.510	-1.477	-1.500
Water	-1.508	-1.599	-1.603	-1.586	-1.574	-1.540	-1.533	-1.571	-1.538	-1.561
Supplementary education	-1.523	-1.614	-1.618	-1.601	-1.590	-1.555	-1.549	-1.586	-1.554	-1.576
Tuition	-1.676	-1.766	-1.770	-1.753	-1.742	-1.707	-1.701	-1.738	-1.706	-1.728
Communication	-2.344	-2.434	-2.438	-2.421	-2.410	-2.376	-2.369	-2.406	-2.374	-2.396
Average	-0.795	-0.887	-0.891	-0.874	-0.862	-0.827	-0.821	-0.859	-0.826	-0.848

Table 11: Percent Deviation of Selected Before-Tax Commodity Prices from the Baseline (Case A)

Commodity	2005	2010	2015
Communication	0.267	1.961	6.304
Tuition	0.186	1.305	5.457
Supplementary education	0.165	1.185	4.429
Water	0.168	1.196	3.996
Household durable goods	0.152	1.013	4.065
Other heating and lighting	0.141	0.992	3.505
Amusement service	0.133	0.923	3.499
Cooked food	0.126	0.895	3.353
Transportation	0.130	0.923	3.336
Medical equipment	0.146	0.863	3.406
Medical service	0.077	0.500	1.897
Clothing related service	0.072	0.454	1.947
Vegetable	0.042	0.459	1.850
Interior decoration	0.078	0.454	1.903
Car related expenditure	0.086	0.429	1.914
Household goods	0.074	0.467	1.785
Books	0.032	0.410	1.652
Other clothing	0.081	0.285	1.479
Rent	0.046	0.299	1.415
Foot wear	0.071	0.233	1.216
Average	0.089	0.592	2.417

Table 12: Percent Deviation of Selected Sectors' Output from the Baseline (Case A)

Sector	2005	2010	2015
Aircraft and its maintenance	0.374	2.974	7.346
Processed agricultural product	0.200	1.560	4.123
Non-residential construction (wooden)	0.094	1.069	2.273
Other precision machine	0.075	0.847	2.484
Timepiece	0.081	0.922	1.838
Hotel and inn	-0.196	-1.437	-3.956
Heat supply	-0.202	-1.595	-3.775
Fruit	-0.218	-1.619	-4.033
Air transportation	-0.220	-1.628	-4.279
Broadcasting	-0.237	-1.807	-3.975
Beverage	-0.248	-1.750	-4.117
Transportation related service	-0.227	-1.757	-4.167
Fishery	-0.223	-1.699	-4.498
Sewer	-0.231	-1.841	-4.428
Processed sea food	-0.224	-1.756	-4.805
Hairdressing	-0.257	-1.885	-5.054
Life insurance	-0.274	-2.090	-5.713
Slaughtering	-0.251	-1.952	-6.642
Other civilian-use electrical apparatus	-0.321	-2.469	-6.083
Communication	-0.358	-2.734	-6.326
Total	-0.090	-0.665	-1.598

Table 13: Percent Deviation of Selected Sectors' Price from the Baseline (Case A)

Sector	2005	2010	2015
Communication	0.307	2.319	6.857
Life insurance	0.277	1.932	6.784
Electricity	0.264	1.908	6.261
Barley and cereal	0.268	1.727	5.519
Postal service	0.219	1.518	5.401
Agricultural service	0.197	1.355	4.296
Heat supply	0.157	1.132	4.242
Air transportation	0.175	1.184	3.987
Radio, TV, and stereo	0.158	1.183	3.912
Freight transportation	0.160	1.138	3.909
Processed sea food	0.187	1.095	3.853
Hairdressing	0.152	1.040	4.072
Waterworks	0.156	1.106	3.695
Property insurance	0.155	1.098	3.738
Broadcasting	0.141	1.107	3.701
Gas supply	0.035	0.247	0.840
Other non-ferrous metal	-0.021	-0.039	1.161
Paddy	0.016	0.045	0.843
Other precision machine	0.033	0.035	0.672
Aircraft and its maintenance	0.083	-0.299	0.079

Table 14: Mean of Percent Deviation of Selected Commodity Demand for Each Age-Group from the Baseline (Case B)

	Age Group									
Commodity	Under 24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	Over 65
Foot wear	-4.493	-1.091	-2.409	-1.281	-0.180	-2.217	-3.683	-2.798	-3.970	-3.726
Textile	-5.423	-2.044	-3.352	-2.233	-1.141	-3.162	-4.616	-3.737	-4.901	-4.658
Miscellaneous	-5.434	-2.047	-3.358	-2.237	-1.142	-3.167	-4.624	-3.744	-4.910	-4.667
Rent	-5.556	-2.187	-3.493	-2.376	-1.286	-3.303	-4.753	-3.877	-5.037	-4.796
Clothing related service	-5.647	-2.275	-3.581	-2.464	-1.373	-3.391	-4.842	-3.965	-5.127	-4.885
Underwear	-5.680	-2.314	-3.617	-2.502	-1.414	-3.428	-4.877	-4.001	-5.160	-4.919
Clothes (western)	-5.704	-2.333	-3.638	-2.522	-1.432	-3.448	-4.898	-4.021	-5.182	-4.940
Housework related service	-5.773	-2.398	-3.705	-2.588	-1.496	-3.515	-4.967	-4.089	-5.251	-5.009
Amusement durables	-5.851	-2.482	-3.787	-2.671	-1.581	-3.597	-5.047	-4.171	-5.331	-5.090
Fruit	-5.852[a]	-2.486	-3.790	-2.675	-1.585	-3.600	-5.050	-4.174	-5.334	-5.092
Medical equipment	-7.292	-3.972	-5.257	-4.159	-3.086	-5.070	-6.497	-5.634	-6.777	-6.539
Cereal	-7.325	-4.016	-5.297	-4.202	-3.132	-5.111	-6.534	-5.674	-6.813	-6.576
Edible oil and seasoning	-7.467	-4.158	-5.439	-4.345	-3.273	-5.253	-6.676	-5.816	-6.955	-6.717
Cooked food	-7.474	-4.159	-5.441	-4.345	-3.275	-5.254	-6.680	-5.817	-6.959	-6.721
Civilian-use durables	-7.538	-4.218	-5.502	-4.405	-3.332	-5.315	-6.742	-5.879	-7.022	-6.784
Electricity	-7.619	-4.324	-5.601	-4.509	-3.443	-5.415	-6.833	-5.976	-7.111	-6.875
Supplementary education	-8.310	-5.019	-6.291	-5.204	-4.142	-6.106	-7.520	-6.664	-7.798	-7.561
Other heating and lighting	-8.783	-5.516	-6.779	-5.700	-4.644	-6.596	-8.000	-7.150	-8.276	-8.041
Water	-9.313	-6.066	-7.322	-6.249	-5.200	-7.139	-8.535	-7.690	-8.809	-8.575
Communication	-10.866	-7.661	-8.899	-7.842	-6.808	-8.719	-10.095	-9.261	-10.365	-10.134
Average	-6.792	-3.460	-4.750	-3.647	-2.569	-4.562	-5.996	-5.129	-6.277	-6.038

a) Demands for other clothing instead of fruit.

Table 15: Percent Deviation of Selected Before-Tax Commodity Prices from the Baseline (Case B)

Commodity	2008	2010	2015
Communication	12.422	16.990	4.770
Water	7.903	10.605	2.559
Supplementary education	7.793	10.040	1.726
Transportation	6.236	8.000	1.566
Tuition	8.957	11.085	0.683
Other heating and lighting	6.587	8.270	1.071
Amusement service	6.207	7.838	1.124
Medical equipment	6.015	7.544	1.242
Restaurant	5.489	7.054	1.359
Liquor	4.779	6.277	1.538
Foot wear	1.208	2.009	0.625
Vegetable	1.924	2.473	-0.035
Interior decoration	3.356	3.844	-0.191
Housing facility and its maintenance	4.416	5.022	-0.616
Clothing related service	3.368	3.886	-0.260
Other clothing	2.188	2.529	0.288
Cereal	3.820	4.343	-0.468
Car related expenditure	3.335	3.799	-0.401
Rent	2.184	2.523	-0.163
Fruit	4.323	4.259	-2.055
Average	4.101	5.007	0.338

Table 16: Percent Deviation of Selected Sectors' Output from the Baseline (Case B)

Sector	2008	2010	2015
Aircraft and its maintenance	16.423	27.407	15.305
Processed agricultural product	8.808	14.400	7.263
Leather foot wear	4.642	6.925	4.567
Timepiece	4.531	7.463	4.258
Non-residential construction (other than wooden)	4.658	7.338	4.266
Processed meat product	-8.072	-12.301	-6.819
Cosmetics and toothpaste	-8.205	-12.481	-7.069
Fruit	-8.848	-13.251	-7.251
Air transportation	-8.499	-12.928	-7.498
Hairdressing	-10.343	-15.039	-6.853
Fishery	-8.831	-12.950	-7.681
Processed seafood	-8.821	-13.243	-8.177
Transportation related service	-8.985	-13.457	-7.918
Sewer	-9.089	-13.602	-8.174
Beverage	-9.743	-14.508	-7.931
Broadcasting	-9.113	-13.768	-8.426
Life insurance	-11.037	-16.311	-8.545
Slaughtering	-10.127	-15.531	-9.576
Civilian-use electrical apparatus	-12.702	-18.907	-10.752
Communication	-13.606	-19.913	-11.766
Total	-3.655	-5.422	-2.770

Table 17: Percent Deviation of Selected Sectors' Price from the Baseline (Case B)

Sector	2008	2010	2015
Communication	14.070	20.036	7.320
Barley and cereal	10.723	16.028	7.854
Electricity	12.501	17.098	4.504
Life insurance	12.961	17.942	4.236
Agricultural service	8.658	12.199	4.160
Postal service	10.221	13.268	2.280
Air transportation	7.501	10.270	3.054
Broadcasting	6.798	9.375	3.138
Civilian-use electrical apparatus	7.727	10.283	2.531
Forage and organic fertilizer	6.550	9.086	2.969
Waterworks	7.320	9.808	2.366
Property insurance	7.065	9.462	2.390
Transportation related service	6.826	9.115	2.412
Processed seafood	7.242	9.405	2.252
Other foods	6.398	8.585	2.291
Chemical fertilizer	1.951	1.500	-1.868
Paddy	0.775	0.053	-2.069
Fruit	3.578	2.528	-4.062
Aircraft and its maintenance	-1.181	-2.745	-2.374
Non-residential construction (wooden)	2.467	0.841	-4.404

Figure 1: Linkage Mechanism