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7

The Effects of Demographic Change on Health and Medical Expenditures
A Simulation Analysis

Satoshi Nakanishi and Noriyoshi Nakayama

7.1 Introduction

In Japan, spending for medical care reached 25,790 billion yen in 1994. Between 1960 and 1994, medical expenditures grew at an annual rate of 12.3 percent, faster than the 10.1 percent annual growth of the gross domestic product (GDP) during the same period. As a result, medical expenditures as a percentage of GDP doubled, from 2.5 percent in 1960 to 5.4 percent in 1994. The largest average annual increases in medical spending occurred in the 1960s and 1970s (19.9 percent and 17.2 percent, respectively), while 1980 ushered in a period of relatively slow growth; from 1980 to 1994, medical expenditures grew at an average annual rate of only 5.5 percent (see fig. 7.1). Since the 1980s, the Japanese government's cost containment strategy, which limits reimbursement rates while increasing self-payments, has slowed the rate of growth. Nonetheless, in 1994 the average per capita medical cost for people aged sixty-five and over was 532,290 yen, 4.8 times higher than the per capita costs for those under sixty-five.

Demographic change was responsible for roughly one-fourth (26.8 percent) of the growth in medical costs between 1980 and 1990. In 1996 the proportion of the Japanese population aged sixty-five and over exceeded 15 percent. According to the United Nations definition, a society is an *aging society* when the ratio of the population aged sixty-five and over exceeds 7 percent, and is an *aged society* when this ratio exceeds 14 percent.

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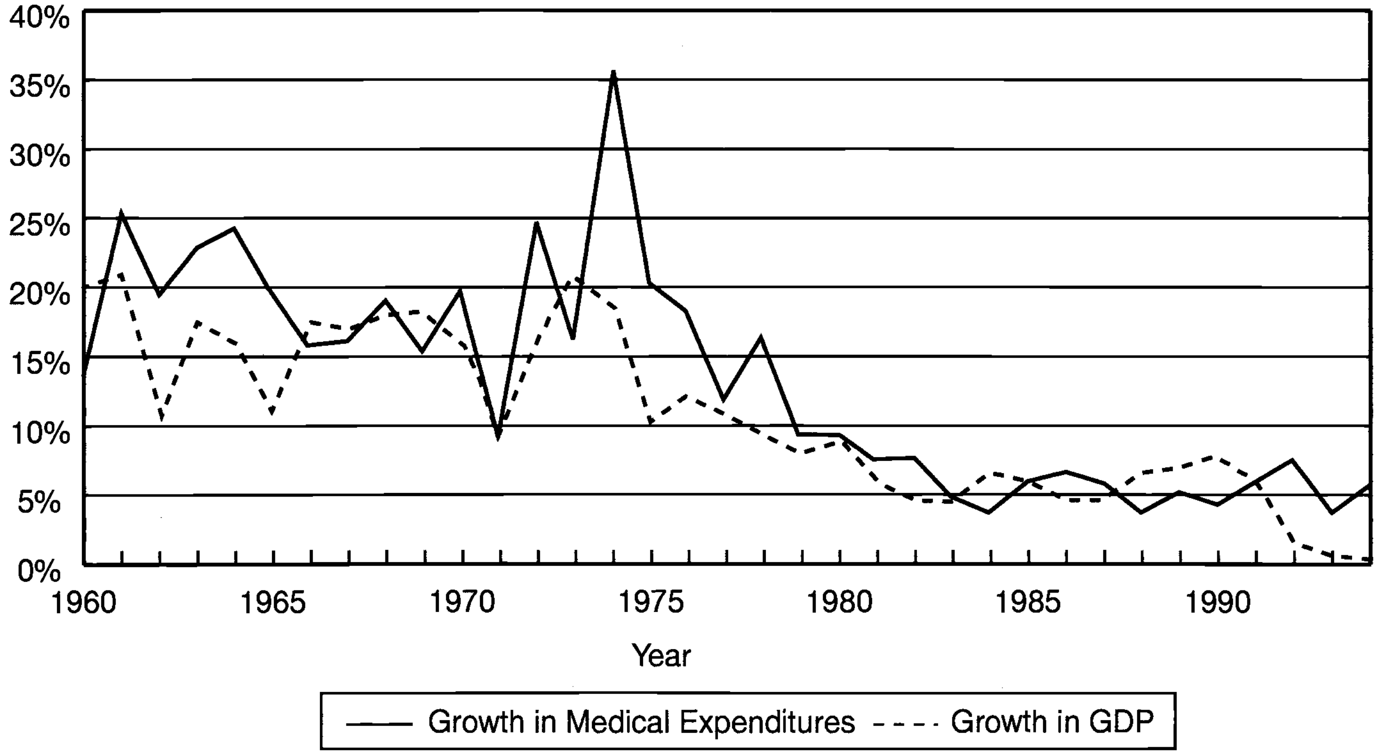

Fig. 7.1 Percent growth in medical care expenditures and GDP in Japan for fiscal years 1960–94
Sources: Kokumin Keizai Keisan Nenpō (Economic Planning Agency), and Kokumin Iryōhi (Ministry of Health and Welfare).

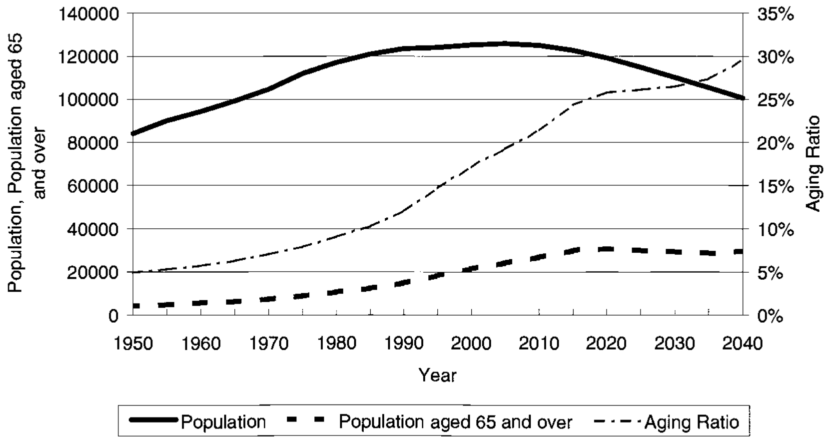

Fig. 7.2 Changes in Japanese population, population aged sixty-five and over, and aging ratio, 1950–2040

Sources: Jinkō Dōtai Chōsa (Ministry of Health and Welfare), and Ogura and Kurumisawa (1994).

Japanese society thus is already an aged society. Figure 7.2 illustrates the growth, and then decline, in Japan's total population, the population growth of those aged sixty-five and over, and the aging ratio (that is, the percentage of the population aged sixty-five and over) from 1950 to 2040. The total population is projected to peak around 2010, then to decrease gradually until 2040. The total over-sixty-five population will rise gradually between the 1990s and the 2010s, then remain almost constant after 2020. The aging ratio is expected to rise rapidly, however: In 1990 the aging ratio was 12 percent; in 2020 it will rise to 25.8 percent, and in 2040 it will reach 29.5 percent.

Since an aging population will likely result in sharp rises in medical expenditures, the Japanese government has been studying various proposals for dealing with this problem (e.g., raising the rate of self-payment). The purpose of this study is to analyze the effect of the aging of the population on the health sector and on the economy as a whole. We are concerned chiefly with (a) the effect of population aging on future medical care costs; (b) the effect of cost containment strategies on medical care expenditures; and (c) the extent to which licensing systems can or should be used to control the flow of new entrants into the medical profession.

Some of these issues have already been analyzed using macroeconometric models (Shakaihoshō-moderu-kaihatsu-kenkyūkai 1979; Hayashi et al. 1980; Hayashi, Kishi, and Mikami 1981; Nishina 1982; Kishi 1990; Inada et al. 1992). However, because these studies used annual data, their degrees of freedom are very limited. An alternative would be to use a simulation method, as Denton and Spencer (1975, 1983a,b, 1988) did in their examination of the relationship between the Canadian economy and the health care sector. In their model, household behavior depends on static demand theory; in ours, household behavior is formulated with a Grossman-type dynamic model (Grossman 1972).[1] This is a notable feature of our research: Until now, no study of the health care sector has used simulation methods and included a Grossman model.

The plan of the paper is as follows. First we estimate the parameters of several functions: the demand for health care and medical care services, consumption, government expenditures, exports, and imports. Then we provide an overview of the simulation model, report the results of the experiments, and finally provide a summary of our findings and briefly discuss the conclusions we draw from them.

7.2 Preliminary Estimation of the Simulation Model

7.2.1 Household Optimization Behavior

First we consider household behavior, which, as explained above, depends on the Grossman model in our model. In the early 1970s, Grossman (1972) turned to human capital theory to explain the demand for health. Medical care is, of course, different from other goods and services. Households do not gain utility from medical care services per se. Yet they do seek good health status and, therefore, demand medical care services as one of the inputs to produce it. When a person's health drops below a certain level, he or she dies. Because health lasts for more than one period and does not depreciate instantly, it may be regarded as a stock. Households make investments in health (their "stock") to compensate for its depreciation. In our model, such investments take the form of the purchase of medical care services, the demand for which derives from the health production function. This is the investment theory of demand for medical care proposed by Grossman. Adopting his model makes it possible to simulate not only changes in the demand for medical care but also changes in health status.

We formulate the maximization problem of a household as follows. A household maximizes the following intertemporal utility function subject to the following two constraints:

(1) $$\max U(t) = \int_0^T e^{-\rho t}[\alpha_0 e^{\eta_1 \mathrm{AGE}(t)} H(t)^{\alpha_1} + \beta_0 C(t)\beta_1]dt,$$

(2) subject to $$\dot{A}(t) = r(t)A(t) + w(t) - \gamma_0 p(t)^{\gamma_1} w(t)^{1-\gamma_1} I(t) - C(t)$$

(3) $$\dot{H}(t) = I(t) - \delta(t)H(t),$$

1. Wagstaff (1986, 1993) makes use of the Grossman model. Johansson and Lofgren (1995) have expanded the Grossman model theoretically.

where $A(t)$ is the stock of financial assets, $\dot{A}(t)$ is its rate of change over time, $C(t)$ is consumption of goods other than medical care services, $H(t)$ is health capital, $\dot{H}(t)$ is its rate of change over time, $I(t)$ is gross investment of health, $r(t)$ is the interest rate, $w(t)$ is wages, and $\delta(t)$ is the rate of depreciation of health. Furthermore, $p(t) = \theta(t)P_M(t)/P_C(t)$, $\mathrm{AGE}(t) = \mathrm{POP65}(t)/\mathrm{POP}(t) \times 100$, where $\theta(t)$ is the self-payment rate, $P_M(t)$ is the price of medical care, $P_C(t)$ is the price of goods other than medical care services, POP65(t) is the percentage of the population aged sixty-five and over, and POP(t) is population.

Equation (2) shows a household's asset accumulation. A household produces a flow of health through an input of medical care and time. Therefore, the cost function of a flow of health is the function of the relative price of medical care services, wages, and gross investment in health capital. We specify the cost function as the third term on the right in equation (2). In equation (3), the household invests in health and accumulates health every year, but health is depreciated by $\delta(t)$. The rate of depreciation of health depends on the individual's age.

By solving this optimization problem, we derive the following conditions.

$$(4)\quad e^{-\rho t}\alpha_0 e^{\eta_1 \mathrm{AGE}(t)}\alpha_1 H(t)^{\alpha_1-1} = \gamma_0\lambda(t)p(t)^{\gamma_1}w(t)^{1-\gamma_1}\left[-\gamma_1\frac{\dot{p}(t)}{p(t)} - (1-\gamma_1)\frac{\dot{w}(t)}{w(t)} + \delta(t) + r(t)\right]$$

$$(5)\quad -\rho + (\beta_1 - 1)\frac{\dot{C}(t)}{C(t)} = \frac{\dot{\lambda}(t)}{\lambda(t)}$$

Equation (4) shows the equilibrium condition of health capital. The marginal utility of the optimal stock of health capital equals the price of health capital. Equation (5) shows the equilibrium condition of goods other than medical services. With these conditions, we can derive the demand function for health and the demand function for goods other than medical care services. We can also obtain the derived demand equation for medical care services by using Shepherd's lemma in the cost function of the flow of health. The demand equations are as follows:[2]

$$(6)\quad \ln H(t) = A_0 + \frac{\beta_1 - 1}{\alpha_1 - 1}\ln C(t) + \frac{\gamma_1}{\alpha_1 - 1}\ln p(t) + \frac{1-\gamma_1}{\alpha_1 - 1}\ln w(t) + \frac{\delta_1 - \eta_1}{\alpha_1 - 1}\mathrm{AGE}(t) + \frac{1}{\alpha_1 - 1}r(t),$$

2. The derivation of the demand equation for health, the demand equation for consumption goods other than medical services, and the derived demand for medical services are shown in the appendix in detail.

Table 7.1 Estimation Results for Household Behavior

	Coefficient	t-value
A_0	1.046	0.345
α_1	0.164	0.466
η_1	0.395	7.466
β_1	0.137	0.532
δ_1	0.035	4.544
B_0	0.237	0.422
C_0	0.003	0.232

$$\text{(7)} \quad \ln M(t) = B_0 + (\gamma_1 - 1)\ln p(t) + (1 - \gamma_1)\ln w(t) + \ln H(t) + \delta_1 \mathrm{AGE}(t),$$

$$\text{(8)} \quad \ln C(t) = C_0 + \ln C(t-1) - \frac{1}{\beta_1 - 1} r(t).$$

We estimate equations (6), (7), and (8) using Japanese data from 1969 to 1994.[3] As we cannot observe health directly, we use the expected life expectancy at age 0 as the proxy of health. The demand equation for health, the demand equation for other goods, and the derived demand equation for medical care services are estimated by a two-stage nonlinear least squares procedure. Our estimation results are summarized in table 7.1.[4] Those results have the signs that we expected; however, some of the estimated parameters are not statistically significant.

7.2.2 Government Consumption Expenditures

We also need to estimate the government's consumption expenditures. Assuming that these expenditures are a function of GDP and the aging ratio, the government-expenditure equation is as follows:

$$\ln G(t) = \pi_0 + \pi_1 \ln Y(t) + \pi_2 \mathrm{AGE}(t).$$

The estimation period is from 1955 to 1993 and the data sources are listed in note 4. The equations are estimated using ordinary least squares (OLS) techniques. We correct for serial correlation by allowing the residual to follow a first-order autoregressive process and estimate the equations using an iterated Cochrane-Orcutt procedure. Table 7.2 shows the estimation results for this equation.

3. We use another proxy of health other than life expectancy at age 0. We use the reciprocal of the crude death rate. However, the estimation result is almost the same as that of life expectancy at age 0.

4. We have obtained data from the following sources in order to estimate equations in the preliminary estimation section: Kokumin Keizai Keisan Nenpō (Economic Planning Agency), Keizai Tokei Nenpō (Bank of Japan), Kokumin Iryōhi (Ministry of Health and Welfare), and Jinkō Dōtai Chōsa (Ministry of Health and Welfare).

Table 7.2 **Estimation Results of Government Consumption Expenditures Equation**

	Coefficient	*t*-value
π_0	4.344	4.389
π_1	0.524	6.817
π_2	0.035	2.107
ρ	0.888	11.933
$\bar{R}^2$	0.994	

Table 7.3 **Estimation Results of Export Equation**

	Coefficient	*t*-value
ϕ_0	−146.73	−8.091
ϕ_1	−0.280	−2.075
ϕ_2	0.080	8.734
ρ	0.980	30.242
$\bar{R}^2$	0.995	

7.2.3 Export and Import Equations

Finally, we must estimate exports and imports. The equations are formulated as follows:

$$\ln \mathrm{EX}(t) = \phi_0 + \phi_1 \ln\left[\frac{P_{\mathrm{EX}}(t)}{P_{\mathrm{IM}}(t)}\right] + \phi_2 \mathrm{YEAR}$$

$$\ln \mathrm{IM}(t) = \psi_0 + \psi_1 \ln Y(t) + \psi_2 \ln\left[\frac{P_{\mathrm{EX}}(t)}{P_{\mathrm{IM}}(t)}\right] + \psi_3 \mathrm{HSHARE} + \psi_4 \mathrm{YEAR},$$

where EX is export, IM is import, P_{EX} is the price index of export goods, P_{IM} is the price index of import goods, HSHARE is the share of health sector to GDP, and YEAR is time trend. We introduce HSHARE into the import equation because we will investigate the effect of change in the industrial structure.

The estimation period is again 1955 to 1993, and the data sources are listed in note 4. Because of serial correlation, these equations are also estimated using an iterated Cochrane-Orcutt procedure. The estimation results for the export equation are shown in table 7.3 and those for the import equation in table 7.4. The sign of HSHARE is negative, which means that imports decrease when HSHARE rises.

Table 7.4 Estimation Results of Import Equation

	Coefficient	t-value
ψ_0	9.346	0.647
ψ_1	0.069	0.563
ψ_2	1.600	9.780
ψ_3	−0.022	−2.714
ψ_4	−0.010	−1.232
ρ	0.644	5.191
$\bar{R}^2$	0.993	

7.3 An Overview of the Simulation Model

Figure 7.3 provides a schematic representation of our model. The model has two producing sectors: a medical care services sector and a general economic sector. In the *general economic sector,* capital and general labor services (i.e., workers other than physicians and nurses) combine to produce Japan's aggregate output, minus the amount specifically associated with medical care. Nonmedical goods are absorbed by private consumption, government consumption, net exports, and physical investment. In this neoclassical macromodel, the supply of general output is predetermined by the input of labor and capital; savings (i.e., output minus consumption and net exports) automatically must equal physical investment, which, after allowing for depreciation, is added to the aggregate capital stock.

The *medical care service sector* uses capital and the labor services of physicians, nurses, and general workers. Production in both sectors requires combining capital and labor. The stock of capital is assumed to be homogeneous; that is, it can be freely transferred between sectors and earns its marginal product in both of them. General labor also moves freely between the two sectors, and its marginal product is the same in all uses. Physician and nurse services, of course, are relevant only within the medical care service sector.

The economic side of the model is neoclassical, so aggregate production is determined by supply in both the short and the long run. However, the allocation of production across sectors in each period depends on the interaction of supply and demand. On the supply side, labor and capital are drawn into productive activity in each sector to the extent that their rewards are equalized across sectors. Demand in the medical care service sector depends explicitly on the price to the ultimate consumer, wages, the demographic structure, and the demand for health. Higher demand, for example, will cause an increase in price, and hence supply, through the inflow of nonphysician labor and capital. When more resources are allocated to medical care, less output is produced in the general economy.

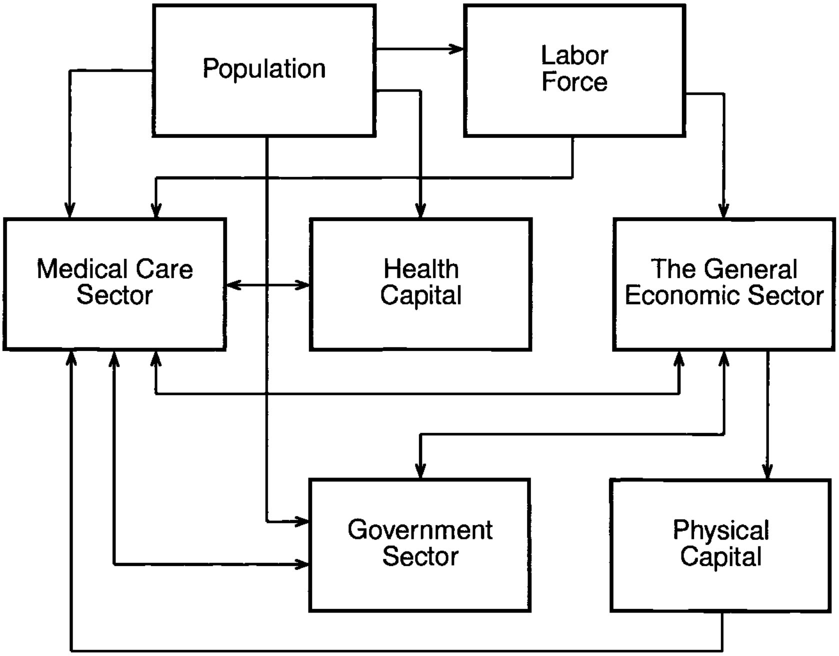

Fig. 7.3 Schematic outline of the population-economy medical care system

The government plays three possible roles in this model: spending (by claiming a share of the output of the general economy), controlling the number of licenses issued to physicians and nurses, and providing subsidies to reduce the private cost of medical care services. Through its subsidies, the government affects the spectral allocation of aggregate output.

We turn now to the components of the model. As shown in table 7.5, the equations are organized into four blocks. A subset of equations in block II (the medical care services sector) must be solved simultaneously; otherwise, the model is entirely recursive and can be solved sequentially.

7.3.1 Block I: Aggregate Economic Activity (equations [1–4])

This block tracks some basic economic aggregates: total labor force (L_t) and total output of the economy (Y_t), obtained by combining the two producing sectors (the medical care service sector, denoted by superscript 1, and the general economic sector, denoted by superscript 2); total capital stock, K_t (the undepreciated portion of last year's stock, plus new investment); and gross investment, I_t. Gross investment (equal to gross saving) is the portion of the economy's gross output not absorbed by current consumption and net export.

Table 7.5 Equations for the Medical Care Macromodel

I. Aggregate Economic Activity

1. $L_t = \sum_{i=1}^{2} \sum_{j=15}^{j\max} q_{ij} \overline{L}_{ijt} = L_t^1 + L_t^2$
2. $K_t = (1 - \varphi)K_{t-1} + I_{t-1}$
3. $Y_t = p_t Q_t^1 + Q_t^2$
4. $Y_t = p_t Q_t^1 + C_t + G_t + \mathrm{I}_t + (\mathrm{EX}_t - \mathrm{IM}_t)$

II. Medical Care Service Sector

5. $M_t = \sum_{i=1}^{2} \sum_{j=25}^{j\max} q_{ij}^{\mathrm{md}} \overline{M}_{ijt}$
6. $N_t = \sum_{i=22}^{i\max} q_i^{\mathrm{nurs}} \overline{N}_{it}$
7. $\ln Q_t^1 = a_0 + \ln \mathrm{POP}_t + \ln H_t + (\gamma_1 - 1) \ln p_t^o + (1 - \gamma_1)\ln(1 - \tau)w_t + \delta_1 \dfrac{\mathrm{OLD}_t}{\mathrm{POP}_t}$
8. $\ln Q_t^1 = \xi_0^1 + \xi_1^1 \ln K_t^1 + \xi_2^1 \ln L_t^1 + \xi_3^1 \ln M_t + (1 - \xi_1^1 - \xi_2^1 - \xi_3^1)\ln N_t$
9. $r_t^1 = \xi_1^1 \left(\dfrac{p_t Q_t^1}{\mathrm{K}_t^1}\right) - \varphi = r_t$
10. $w_t^1 = \xi_2^1 \left(\dfrac{p_t Q_t^1}{\mathrm{L}_t^1}\right) = w_t$
11. $w_t^{\mathrm{md}} = \xi_3^1 \left(\dfrac{p_t Q_t^1}{M_t}\right)$
12. $w_t^{\mathrm{nurs}} = \left(1 - \xi_1^1 - \xi_2^1 - \xi_3^1\right)\left(\dfrac{p_t Q_t^1}{N_t}\right)$
13. $p_t Q_t^1 = r_t^1 K_t^1 + w_t^1 L_t^1 + w_t^{\mathrm{md}} M_t + w_t^{\mathrm{nurs}} N_t$

III. Health Capital Sector

14. $\ln H_t = b_0 + \dfrac{\beta_1 - 1}{\alpha_1 - 1} \ln C_t + \dfrac{\gamma_1}{\alpha_1 - 1} \ln p_t^o + \dfrac{1 - \gamma_1}{\alpha_1 - 1} \ln (1 - \tau)w_t + \dfrac{\delta_1 - \eta_1}{\alpha_1 - 1} \dfrac{\mathrm{OLD}_t}{\mathrm{POP}_t} + \dfrac{1}{\alpha_1 - 1} r_t$

IV. General Economic Sector

15. $\ln C_t = \chi_0 + \ln C_{t-1} + \chi_1 r_t$
16. $\ln G_t = \ln \mathrm{POP}_t + \sigma_0 + \sigma_1 \ln \dfrac{Y_t}{\mathrm{POP}_t} + \sigma_2 \ln \dfrac{\mathrm{OLD}_t}{\mathrm{POP}_t}$
17. $\ln \mathrm{EX}_t = \ln \mathrm{POP}_t = \kappa_0 + \kappa_1 t$
18. $\ln \mathrm{IM}_t = \ln \mathrm{POP}_t + \upsilon_0 + \upsilon_1 \ln \dfrac{Y_t}{\mathrm{POP}_t} + \upsilon_2 \dfrac{p_t Q_t^1}{Y_t}$
19. $\ln Q_t^2 = \zeta_0^2 + \zeta_1^2 \ln(K_t - K_t^1) + (1 - \zeta_1^2) \ln (L_t - L_t^1)$
20. $r_t^2 = \zeta_1^2 \left(\dfrac{Q_t^2}{(K_t - K_t^1)}\right) - \delta = r_t$

Table 7.5 (continued)

21. $w_t^2 = (1 - \zeta_1^2)\left(\dfrac{Q_t^2}{(L_t - L_t^1)}\right) = w_t$

Notes: C = annual private consumption; EX = annual gross export; G = annual government consumption; H = health capital; I = annual gross investment; IM = annual gross import; K = total stock of physical capital at beginning of year; K^1 = capital stock in medical service sector; K^2 = capital stock in general economic sector; L = total employed general labor force; $\overline{L}$ = nonphysician population; L^1 = general worker employed in medical sector; L^2 = general worker employed in general sector; M = employed physician; $\overline{M}$ = physician population; N = employed nurse; $\overline{N}$ = nurse population; OLD = population age sixty-five and over; p = relative price of a unit of medical care service; p^o = out-of-pocket price of a unit of medical care service; POP = total population; q = age-sex-specific labor employment rate for general workers; q^{md} = age-sex-specific labor employment rate for physicians; q^{nurs} = labor employment rate for nurses; Y = gross domestic product; Q^1 = gross product of the medical care service sector; Q^2 = gross product of the general economic sector; r = real interest rate; w = annual earnings of general worker; w^{md} = annual earnings of physician; w^{nurs} = annual earnings of nurse; α_1 = parameter of utility function about health; β_1 = parameter of utility function about consumption; γ_1 = parameter of cost function of health; η_1 = shift parameter of utility function for changing the degree of aging; δ_1 = parameter of health-capital depreciation rate for the degree of aging; a_0 = scale parameter of medical care demand function; b_0 = scale parameter of health demand function; c_0 = parameter of growth rate of private consumption per capita; ξ = parameter of production function in medical care service sector; ζ = parameter of production function in general economic sector; φ = annual rate of depreciation of physical capital; σ = parameter of government expenditure function; τ = overall rate of taxation applied to annual net income; κ = parameter of export function; υ = parameter of import function.

7.3.2 Block II: Medical-Care Service Sector (equations [5–13])

The employment level of physicians and nurses is determined on the supply side in this neoclassical model; the price adjustment assures the full employment of physicians and nurses. The labor supply of physicians and nurses is represented by equations (5) and (6); $\overline{M}$ and $\overline{N}$ represent the number of licensed persons, and q^{md} and q^{nurs} denote the labor force participation rate for medical specialists.

The demand for medical care and its supply are determined in this block. The demand function is presented in equation (7). The demand for medical care services depends on population; the optimal level of health capital; after-tax wage income (i.e., the opportunity cost of the time spent producing health capital), $(1 - \tau)w_t$; and the price of medical care services from the purchaser's point of view (out-of-pocket price), P_t^o. The production of services in equation (8) is equal to current production, which is based on the Cobb-Douglas production function, with inputs of capital, general labor, physician labor, and nurse labor. The supply function itself is implicit: It is derivable from the production function and other equations of block II. Under the assumption that physicians are price-takers and that other inputs receive the rates of return they would have received in the general economic sector, the price of medical care, the wage rates of physicians, the levels of all inputs, and the level (real) output of the sector are calculated by simultaneous solution of the system of nonlinear equations (7) through (13).

7.3.3 Block III: Health Capital Sector (equation [14])

The optimal level of health capital is determined in this block. The stock of health capital depends on per capita consumption, C_t, after-tax wage income, the degree of aging, the out-of-pocket price of medical care services, and on the real interest rate, r_t.

7.3.4 Block IV: General Economic Sector (equations [15–21])

The general economic sector produces the commodities used for general consumption, net export, and physical investment in the economy. Expenditure functions for the sector are presented in equations (15) to (18). Private consumption depends on lagged consumption, C_{t-1}, and on the real interest rate, r_t. Government expenditures are determined by per capita income, Y_t/POP_t, and by the population's age distribution. Net exports depend on the medical sector's income and its share of the total economy, $p_t Q_t^1 / Y_t$.

An aggregate Cobb-Douglas production function is assumed in equation (19), the inputs being capital and general labor. The labor input is calculated in equation (1) by applying age-sex-specific participation to the male and female populations by single years of age. The wage rate, w_t^2, and the rates of return on capital, r_t^2, in this sector are determined under the assumption that factors of production receive their marginal products. The net rate of return on capital also serves as the (real) rate of interest in the economy as a whole, r_t.

7.4 Simulation Experiments and Results

To assess the impact of health policy on health status and medical expenditures, we have made a number of projections based on alternative assumptions about various parameters of the model. As noted, all projections start from labor-participation rates that are in keeping with the 1990 Japanese age-sex distribution. In addition, they start with data on the Japanese economic structure as it was in 1990: parameters of production function, scale parameters, depreciation rate of capital, and so on. The data on the future population are adopted from Ogura and Kurumisawa (1994).

7.4.1 Projection 1: Standard Simulation

Three assumptions underlie our first simulation of the dynamics of the population-medical macromodel: (a) The entrance rate of new physicians (aged twenty-five) does not change; (b) the entrance rate of new nurses

Table 7.6 Standard Simulation Results

Year	Medical Expenditures	Health Status	Medical Expenditures/ GDP	Doctor Income	Nurse Income	Others Income
1990	100.00	100.00	100.00	100.00	100.00	100.00
1995	198.79	108.05	149.08	183.45	172.54	134.65
2000	337.01	106.70	170.37	282.47	268.39	179.63
2005	502.13	99.84	212.97	403.12	382.43	235.88
2010	681.02	88.84	212.97	536.44	513.36	305.63
2015	875.54	75.23	234.26	685.85	665.53	388.98
2020	1,007.04	63.60	212.97	796.70	776.50	484.40
2025	1,070.94	54.09	191.67	850.98	847.09	590.58
2030	1,114.04	46.07	191.67	893.58	920.94	705.32
2035	1,169.81	39.47	170.37	961.15	1,024.72	820.81
2040	1,279.50	34.08	191.67	1,092.87	1,194.74	917.75

(aged twenty-one) does not change; and (c) the out-of-pocket price of medical care does not change. The results of this standard simulation are summarized in table 7.6.

In the year 2000, medical care expenditure will be 3.4 times its 1990 level; in 2010 it will be 6.8 times as much; in 2020, 10.1 times; in 2030, 11.1 times; and in 2040, 12.8 times. The forecast of the annual average growth rate of medical expenditure for the entire period is 4.3 percent. However, even though people will spend more for medical care in the future, aging will make them less healthy and the national health status will gradually decrease, reaching less than half its 1990 level by 2028. The share of medical expenditure in the whole economy (i.e., the GDP) will rise, reaching 10.8 percent in 2015, then gradually decline to 8.5 percent in 2040. During the simulation period, the wages of physicians will grow at 4.1 percent per annum, while the annual growth rate of wages for nurses and general workers will average 4.3 percent and 4.5 percent, respectively.

7.4.2 Projection 2: Cost-Containment Policy

How will the government's attempt to repress the growth rate of medical expenditures below the growth rate of GDP affect the medical care service sector, in particular the out-of-pocket price (self-payment) faced by health care users? Projection 2 simulates the change in these prices resulting from measures to contain medical expenditures; the results are summarized in table 7.7. Self-payment for medical care would have to increase to 1.83 times its 1990 level in 2017, then gradually decrease to 1.67 times that level in 2032, before rising again to 1.82 times the 1990 level in 2040. Figure 7.4 illustrates this transition.

The model also indicates that under a cost-containment policy, the de-

Table 7.7 Simulation Results of Cost-Containment Policy

Year	Medical Expenditures	Health Status	Self-Payment	Medical Expenditures/GDP	Doctor Income	Nurse Income	Others Income
1990	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1995	138.13	98.36	123.97	106.48	127.52	119.93	134.15
2000	184.81	92.14	148.76	106.48	154.85	147.14	177.25
2005	236.14	84.09	165.29	106.48	189.52	179.80	229.70
2010	292.70	74.38	173.55	106.48	230.10	220.20	293.50
2015	354.98	63.20	181.82	106.48	277.61	269.38	368.91
2020	422.83	54.81	181.82	106.48	334.07	325.60	454.91
2025	493.75	48.48	173.55	106.48	392.46	390.67	550.57
2030	561.02	42.89	165.29	106.48	449.35	463.11	652.99
2035	610.22	37.78	165.29	106.48	500.68	533.79	752.12
2040	625.41	33.01	181.82	106.48	534.66	584.49	822.89

cline in national health status is more rapid than in the standard projection; the health indicator drops below half the 1990 level in 2025. Figure 7.5 compares the transition of health status under the two projections.

The annual growth rate of medical expenditures also decreases under cost containment, from 4.3 percent for the standard projection (Projection 1) to 3.6 percent (Projection 2). This comparison is shown in figure 7.6.

7.4.3 Projection 3: Increase in Medical Licenses

A rise in the market entrance rate for new physicians should, of course, decrease the annual growth rate of their wages. The number of medical licenses issued also affects productivity in the medical care sector and in the economy as a whole. In this projection, therefore, we investigate the effect of increasing the number of medical licenses by 25 percent above the 1990 level. The simulation results are summarized in table 7.8. Under this scenario, the annual growth rate of physician's wages over the period will be slower than in the standard case—3.5 percent, compared to 4.1 percent. Figure 7.7 presents a comparison of the relative wages of physicians and general workers in the above two cases; increasing the number of medical licenses issued suppresses the wage discrepancy between doctors and general workers. Although the demand for medical care does not change in this projection compared with the standard projection, the medical sector's share of GDP decreases, because a rise in the number of physicians releases many general workers from the medical care sector to the general economic sector. As the marginal productivity of physicians is greater than that of general workers in the medical care sector, increasing the supply of physicians encourages the production of goods and services in the general sector. This transition in the ratio of medical expenditure to GDP is presented in figure 7.8.

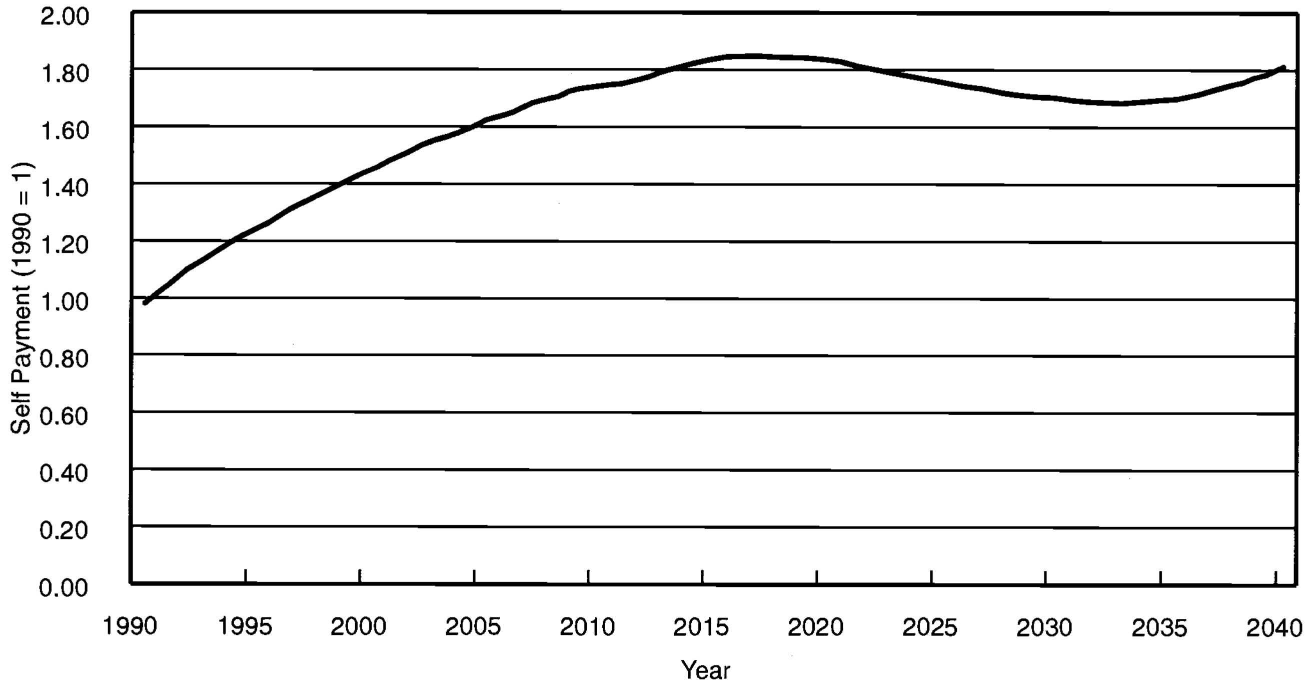

Fig. 7.4 The transition of self-payment

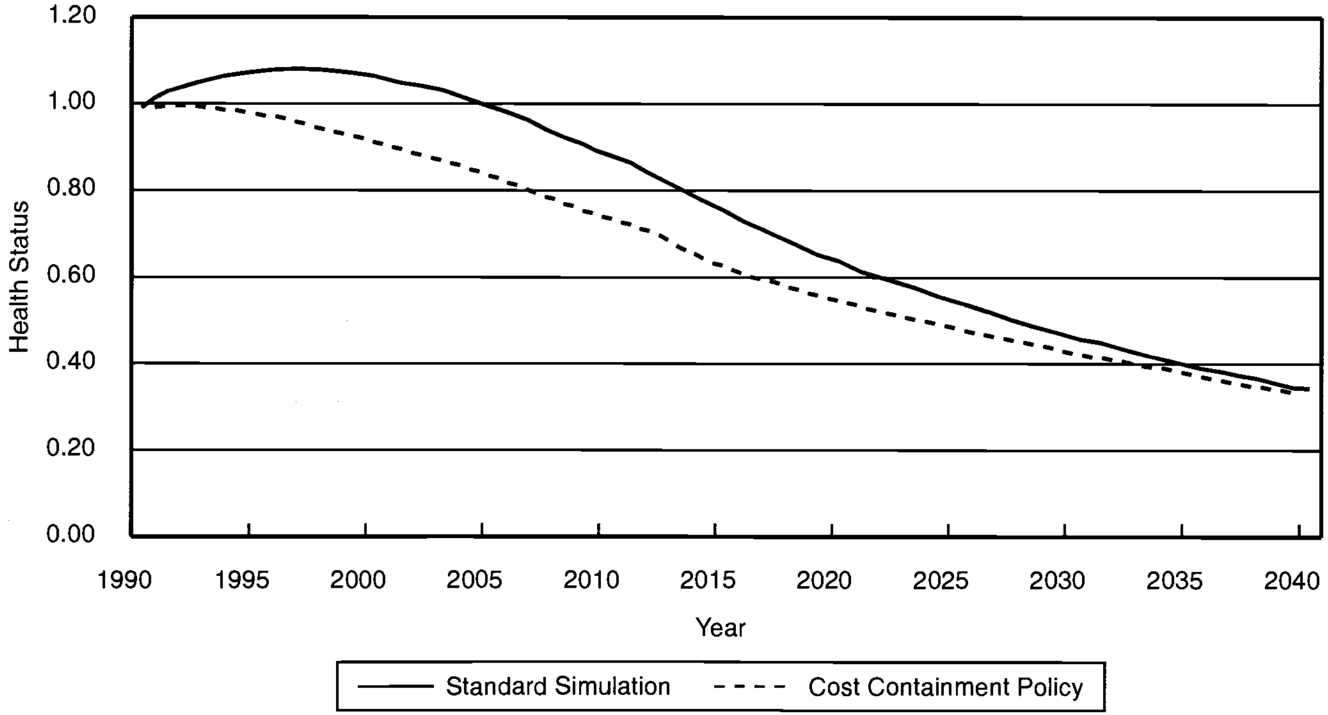

Fig. 7.5 Health status and cost-containment policy

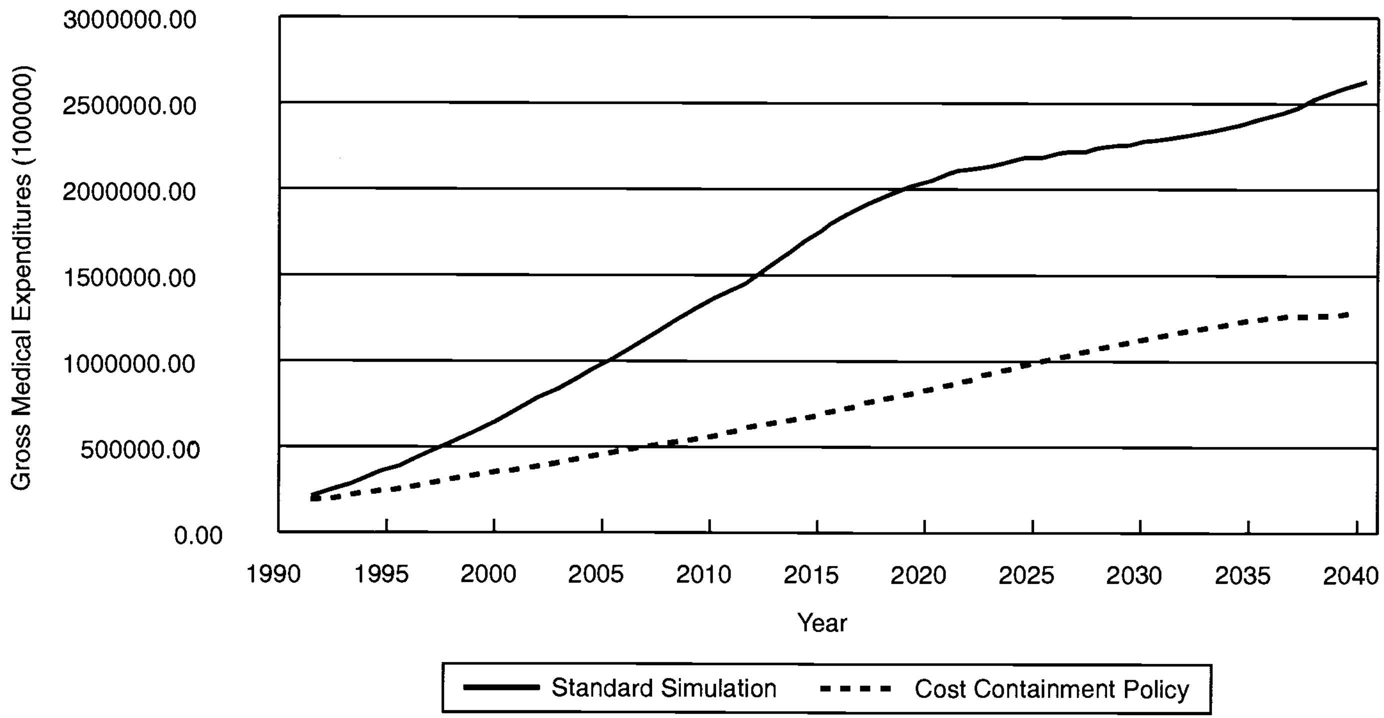

Fig. 7.6 Gross medical expenditures and cost-containment projections

Table 7.8 Simulation Results of Increasing the Number of Physician Licenses

Year	Medical Expenditures	Health Status	Medical Expenditures/ GDP	Doctor Income	Nurse Income	Others Income
1990	100.00	100.00	100.00	100.00	100.00	100.00
1995	197.34	108.09	149.08	176.22	170.95	134.64
2000	331.38	106.83	170.37	260.82	263.57	179.57
2005	488.95	100.06	191.67	362.62	373.46	235.68
2010	661.95	89.15	212.97	472.30	499.15	305.21
2015	848.24	75.59	212.97	592.58	644.79	388.24
2020	973.45	63.97	212.97	676.58	749.93	483.28
2025	1,031.10	54.44	191.67	709.69	815.38	588.99
2030	1,069.97	46.44	170.37	732.45	883.73	703.17
2035	1,120.72	39.83	170.37	775.96	980.85	817.86
2040	1,222.09	34.45	170.37	871.11	1,141.64	913.51

7.4.4 Projection 4: Increase in Nurse Licenses

Projection 4 looks at the effect on economic activity of increasing the ranks of nurses in the health care sector. The simulation results for increasing the number of nursing licenses issued are summarized in table 7.9. This action decreases the annual growth rate of nurses' wages as compared to the standard case (from 4.3 percent to 3.9 percent). Figure 7.9 illustrates the effect on the relative wages of nurses and general workers in the two cases; the wage discrepancy between them is reduced by increasing the number of nursing licenses. As in the preceding scenario, the demand for medical care remains unchanged but the share of medical expenditures in GDP is decreased compared to the standard case. This change is shown in figure 7.10.

7.5 Conclusions

In this study we constructed a model of the Japanese economy in order to analyze the effect of demographic changes and possible changes in health policy on the medical care sector and on the economy as a whole. Using the Grossman model of household behavior, we were able to derive the national demand for health, the demand for consumption goods, and the derived demand for medical services.

Our simulation shows that maintaining the present system of payment for health care as the population ages will result in medical care expenditures' growing at an average annual rate of 4.3 percent between 1991 and 2040. The share of medical expenditure in GDP will reach 10.8 percent in 2015, then gradually begin to decline. Moreover, even though people invest in their futures rather than their present medical care, their health status in the twenty-first century will be lower because of population aging.

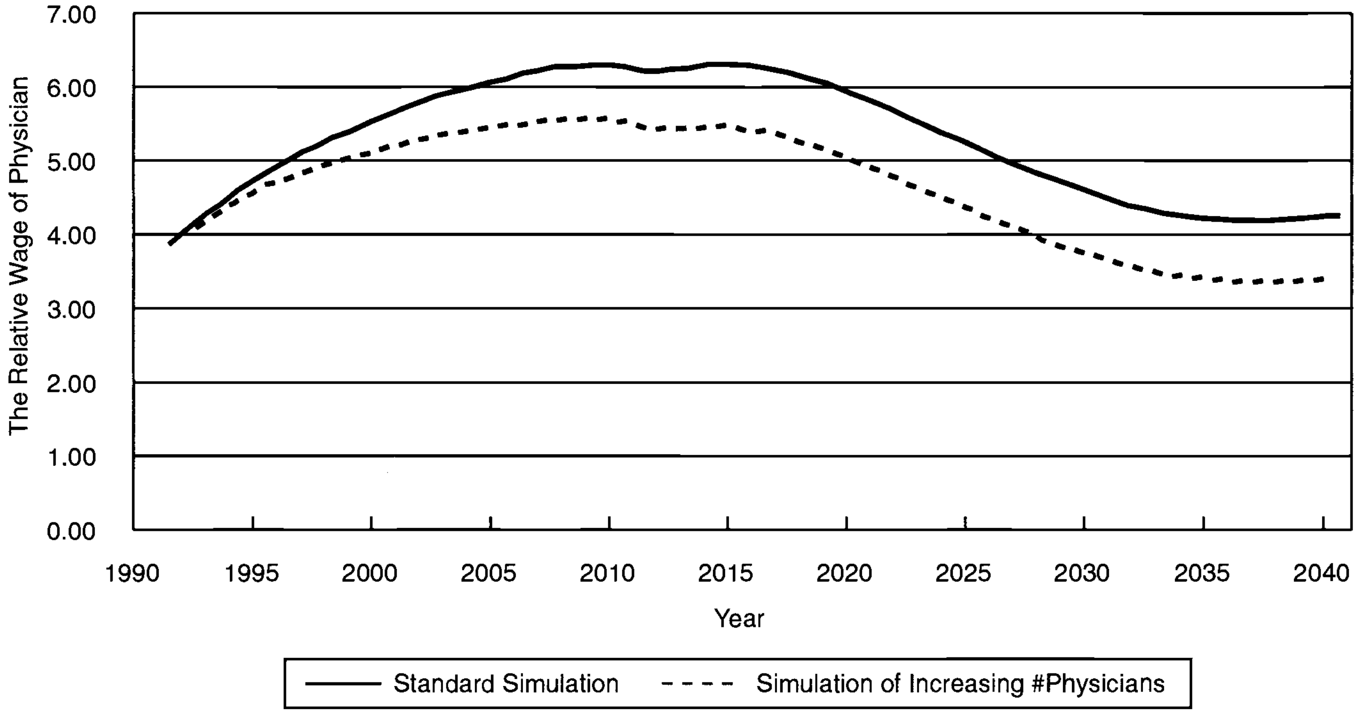

Fig. 7.7 Relative wage of physicians and increasing the number of licenses for physicians

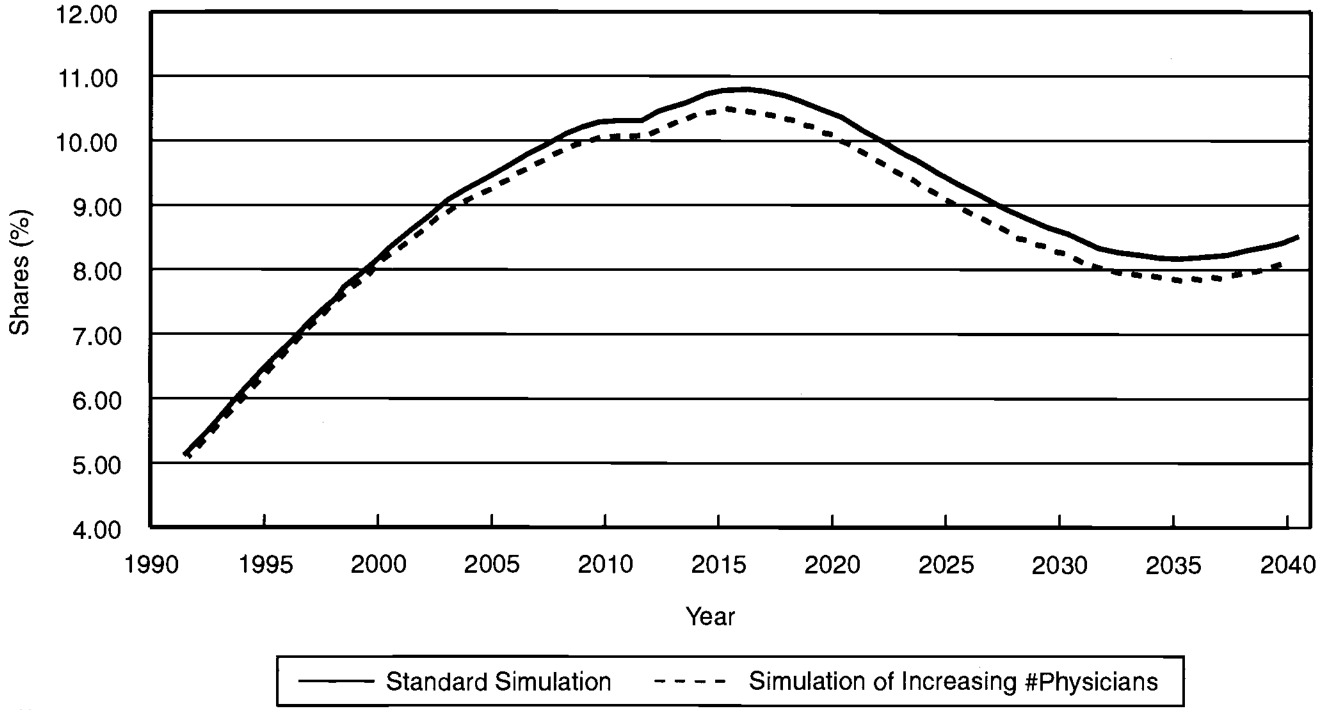

Fig. 7.8 Medical expenditures/GDP and increasing the number of licenses for physicians

Table 7.9 **Simulation Results of Increasing the Number of Nursing Licenses**

Year	Medical Expenditures	Health Status	Medical Expenditures/ GDP	Doctor Income	Nurse Income	Others Income
1990	100.00	100.00	100.00	100.00	100.00	100.00
1995	197.34	108.11	149.08	181.67	163.39	134.65
2000	331.39	106.88	170.37	278.17	246.13	179.55
2005	491.28	100.13	191.67	395.44	342.07	235.61
2010	667.18	89.25	212.97	524.55	448.86	305.04
2015	854.07	75.72	234.26	668.68	568.84	387.94
2020	979.59	64.12	212.97	774.48	648.49	482.80
2025	1,039.74	54.62	191.67	825.30	693.03	588.26
2030	1,078.51	46.40	170.37	865.29	741.16	702.05
2035	1,133.46	40.02	170.37	930.19	814.62	816.17
2040	1,239.14	34.65	170.37	1,058.31	942.04	910.87

Controlling medical expenditures through cost containment will require the Japanese people to accept both major increases in the rate of self-payment for medical care and a decline in national health status. Alternatively, increasing the supply of medical specialists would reduce the share of medical expenditure in the economy as a whole. Of course, taking this course would require Japan to raise its investment in the education of nurses and physicians.

Appendix

The Derivation of Demand Equations

We derive the demand function for health, the demand for other goods, and derived demand for medical services. We maximize the next utility function subject to constraints.

(A1) $$U(t) = \int_0^T e^{-\rho t}[\alpha_0 e^{\eta_1 \mathrm{AGE}(t)} H(t)^{\alpha_1} + \beta_0 C(t)^{\beta_1}]dt$$

subject to

(A2) $$\dot{A}(t) = r(t)A(t) + w(t) - \gamma_0 p(t)^{\gamma_1} w(t)^{1-\gamma_1} I(t) - C(t)$$

(A3) $$\dot{H}(t) = I(t) - \delta(t)H(t)$$

Hamiltonian is

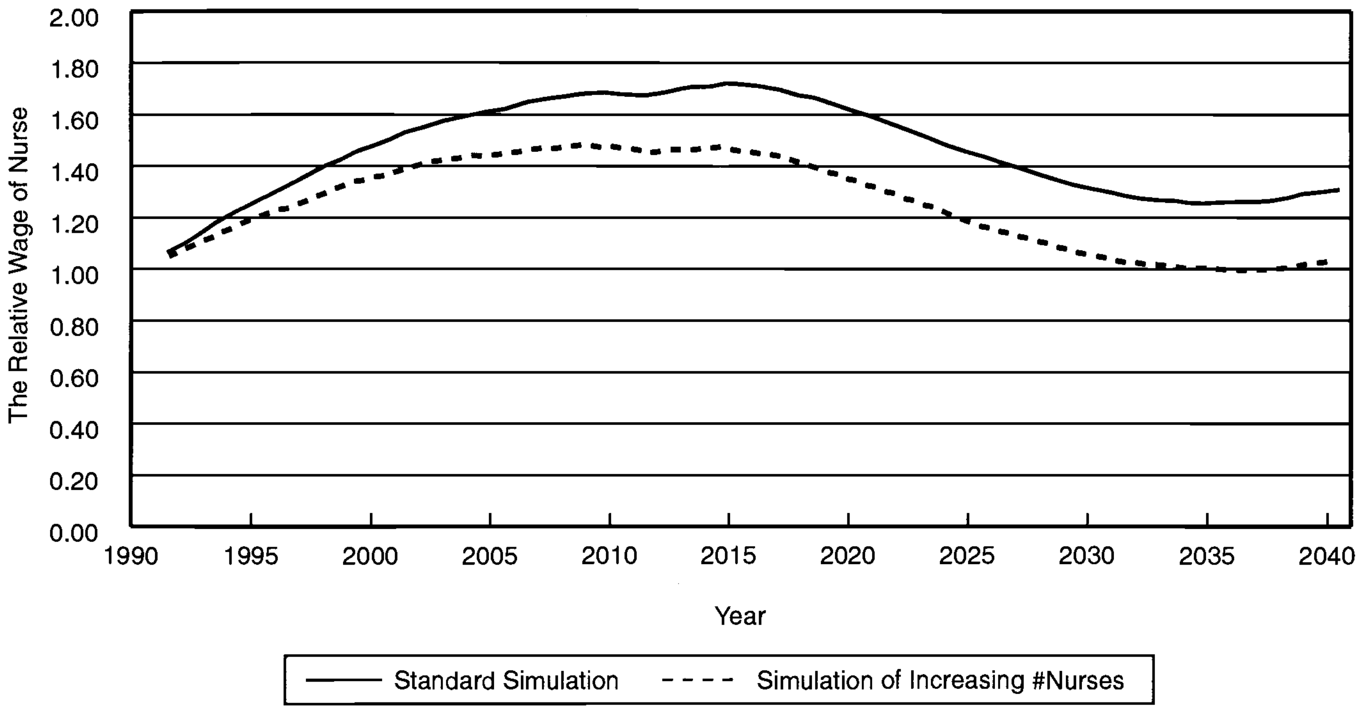

Fig. 7.9 **The relative wages of nurses and increasing the number of licenses for nurses**

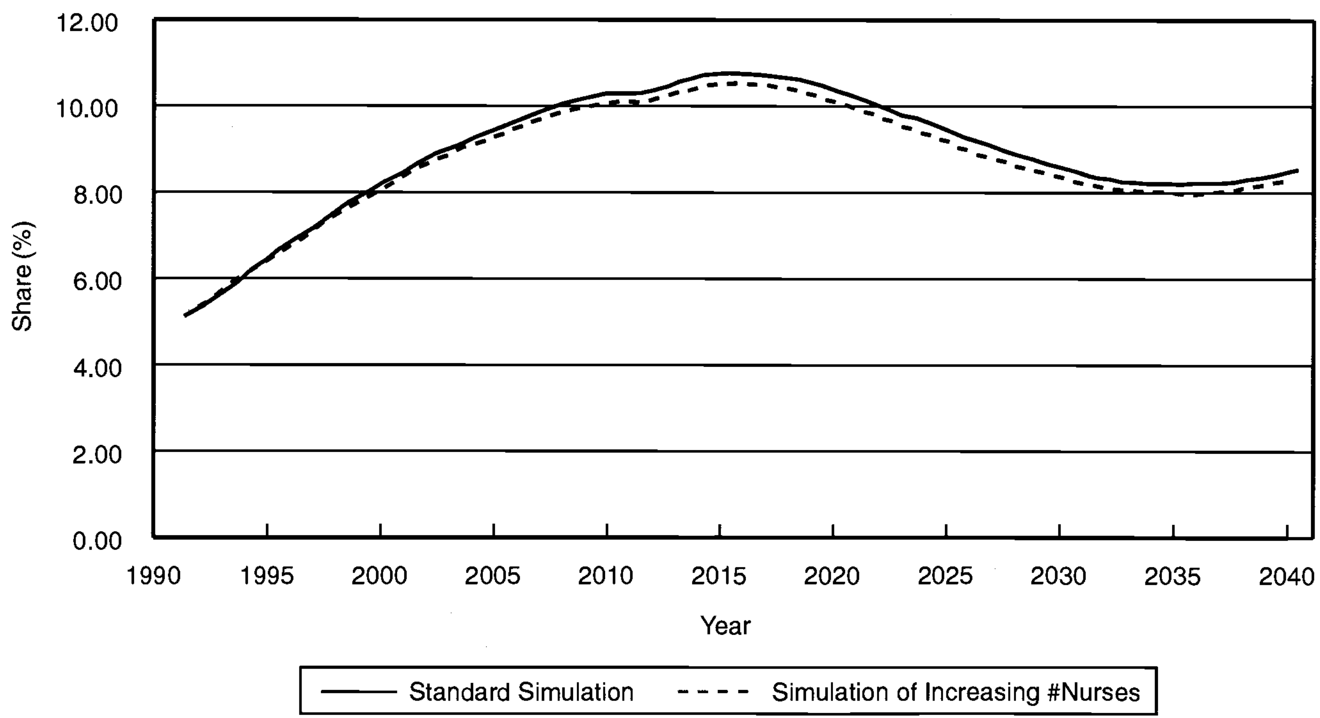

Fig. 7.10 Medical expenditures/GDP and increasing the number of licenses for nurses

(A4) $$L(t) = e^{-\rho t}[\alpha_0 e^{\eta_1 \mathrm{AGE}(t)} H(t)^{\alpha_1} + \beta_0 C(t)^{\beta_1}] + \lambda(t)[r(t)A(t) + w(t) - \gamma_0 p(t)^{\gamma_1} w(t)^{1-\gamma_1} I(t) - C(t)] + \mu(t)[I(t) - \delta(t)H(t)].$$

The following conditions are required to hold:

(A5) $$\frac{\partial L(t)}{\partial I(t)} = -\lambda(t)\gamma_0 p(t)^{\gamma_1} w(t)^{1-\gamma_1} + \mu(t) = 0,$$

(A6) $$\frac{\partial L(t)}{\partial C(t)} = e^{-\rho t}\beta_0\beta_1 C(t)^{\beta_1 - 1} - \lambda(t) = 0,$$

(A7) $$\frac{\partial L(t)}{\partial A(t)} = -\dot{\lambda}(t) = r(t)\lambda(t),$$

(A8) $$\frac{\partial L(t)}{\partial H(t)} = -\dot{\mu}(t) = e^{-\rho t}\alpha_0 e^{\eta_1 \mathrm{AGE}(t)}\alpha_1 H(t)^{\alpha_1 - 1} - \mu(t)\delta(t),$$

(A9) $$A(T)\lambda(T) = 0, \text{ and}$$

(A10) $$\mu(t)[H(T) - \overline{H}] = 0.$$

From equation (A5),

(A11) $$\mu(t) = \lambda(t)\gamma_0 p(t)^{\gamma_1} w(t)^{1-\gamma_1}.$$

The derivative of equation (A11) is

(A12) $$\dot{\mu}(t) = \gamma_0[\dot{\lambda}(t)p(t)^{\gamma_1} w(t)^{1-\gamma_1} + \lambda(t)\gamma_1 p(t)^{\gamma_1 - 1}\dot{p}(t)w(t)^{1-\gamma_1} + \lambda(t)p(t)^{\gamma_1}(1-\gamma_1)w(t)^{-\gamma_1}\dot{w}(t)].$$

Substituting equations (A7), (A8), and (A11) into (A12),

(A13) $$e^{-\rho t}\alpha_0 e^{\eta_1 \mathrm{AGE}(t)}\alpha_1 H(t)^{\alpha_1 - 1} = \gamma_0\lambda(t)p(t)^{\gamma_1} w(t)^{1-\gamma_1} \left[-\gamma_1\frac{\dot{p}(t)}{p(t)} - (1-\gamma_1)\frac{\dot{w}(t)}{w(t)} + \delta(t) + r(t)\right].$$

From equation (A13), we can derive the demand function for health.

(A14) $$\ln H(t) = A_0 + \frac{\beta_1 - 1}{\alpha_1 - 1}\ln C(t) + \frac{\gamma_1}{\alpha_1 - 1}\ln p(t) + \frac{1-\gamma_1}{\alpha_1 - 1}\ln w(t) + \frac{\delta_1 - \eta_1}{\alpha_1 - 1}\mathrm{AGE}(t) + \frac{1}{\alpha_1 - 1}r(t)$$

We use the next equations in order to derive the demand function for health.

$$\ln\left\{\frac{\delta(t)e^{r(t)}}{[-\gamma_1\dot{p}(t)/p(t) - \gamma_2\dot{w}(t)/w(t) + \delta(t) + r(t)]e^{r(t)}}\right\} = 0$$

$$\ln\delta(t) = \delta_0 + \delta_1\mathrm{AGE}(t)$$

From equation (A3) and the above two equations,

$$\text{(A15)} \qquad \ln I(t) = \ln[\dot{H}(t) + \delta(t)H(t)]$$
$$= \ln\left[\frac{\dot{H}(t)}{\delta(t)H(t)} + 1\right] + \ln\delta(t) + \ln H(t)$$
$$= \ln H(t) + \ln\delta(t).$$

From Shepherd's lemma,

$$\text{(A16)} \qquad \frac{\partial[p(t)^{\gamma_1}w(t)^{1-\gamma_1}I(t)}{\partial p(t)} = M(t).$$

Therefore,

$$\text{(A17)} \qquad M(t) = \gamma_0\gamma_1 p(t)^{\gamma_1-1}w(t)^{1-\gamma_1}I(t).$$

From equations (A15) and (A16), we can derive the derived demand equation for medical services.

$$\text{(A18)} \qquad \ln M(t) = B_0 + (\gamma_1 - 1)\ln p(t) + (1 + \gamma_1)\ln w(t) + \ln H(t)$$
$$+ \delta_1\mathrm{AGE}(t)$$

Substituting equation (A6) into (A13)

$$\text{(A19)} \qquad e^{-\rho t}\beta_0\beta_1 C(t)^{\beta_1-1} = \lambda(t)$$

$$\text{(A20)} \qquad -\rho t + \ln\beta_0\beta_1 + (\beta_1 - 1)\ln C(t) = \ln\lambda(t)$$

$$\text{(A21)} \qquad -\rho + (\beta_1 - 1)\frac{\dot{C}(t)}{C(t)} = \frac{\dot{\lambda}(t)}{\lambda(t)}.$$

From equation (A21), we can derive the demand function for other goods.

$$\text{(A22)} \qquad \ln C(t) = C_0 + \ln C(t - 1) - \frac{1}{\beta_1 - 1}r(t)$$

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