How Can Japanese Extended Longevity Be Evaluated?
- An Estimate of a Fruit of Economic Growth -

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Abstract

Substantial improvement in health conditions during 35 years from 1970 to 2005 has made Japan one of the top countries for longevity in the world, which is sometimes referred to as a fruit of economic growth (e.g. Yoshikawa (2003)). This paper tries to quantify value of the improvement by willingness-to-pay (WTP) for the mortality decline during the period, following Murphy and Topel (2003, 2006). Our results show the value may amount to165 trillion per year, about 30 per cent of GDP. An alternative assumption about consumption by the young and the elderly may increase the value by about 20 percent. Possible ranges of the value of WTP are also shown, depending on parameters of utility function. Effects of demographic changes are examined: an increase in population and progress in ageing with fewer children increase the WTP by 30 and 20 trillion yen, respectively. Looking ahead, a limited additional increase in survival rates, and smaller population, are likely to cut the WTP to about 60 trillion yen in 2040. Furthermore, health expenditures required for extended longevity are estimated to be less than a tenth of the WTP. This is a very rough calculation as cost-benefit analysis because other expenditures (e.g. those related to improvements in public sanitation and diets) could be recognized as costs.

JEL Classification Codes: I10, D61
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1. Introduction

The life span of Japanese people has increased dramatically, and is an outcome often attributed to economic growth (e.g., Yoshikawa 2003)[1]. This chapter will try to quantify the advantages of greater longevity. To be specific, we will measure people's willingness-to-pay (WTP) with respect to an increase in the survival rate, $dS = S^1 - S^0$, between S^0 and S^1. We can think of the value of WTP as the economic advantage of longevity.

Wage disparity is often used to study the relationship between prices and risks. In labor markets, jobs with high risk tend to offer higher wages than those with low risk, and such research attempts to determine how wages vary according to jobs' risk characteristics. This price-risk trade-off is often summarized in the value of statistical life (VSL), the premium divided by the additional level of danger, that is, the WTP per unit of additional risk (WTP/dS). This normalized indicator is calculated in many policy evaluation studies. Cropper, Hammitt, and Robinson (2011) provided an overview of recent literature on the VSL[2]. This chapter instead highlights the WTP, putting it in terms of size and scope, before adjusting for dS, because estimating the size itself is a primary purpose here.

However, because of regulations, it is generally difficult to obtain good data on health care from the market, making the method cited above difficult to employ[3]. For instance, rarely do we hear hospitals say that they will provide an obsolete health care service, but at a discount. Under these circumstances, Murphy and Topel (2003, 2006) put forth a method to estimate the WTP. Here, this method is applied to data for Japan to determine the value of the decrease in the mortality rate that occurred in the 35 years from 1970 to 2005. The WTP is estimated based on the population in 2005, and it is also possible to project the effects of future changes in the population on the WTP, as an extension. Furthermore, if we can identify the factors contributing to the greater longevity, it would be possible to calculate their costs. This chapter implements a cost-benefit analysis on trial, following Murphy and Topel (2003).

This chapter is structured as follows. Section 2 reviews literature related to the VSL, WTP, and health capital. Section 3 shows our theoretical framework, in which our model to estimate the WTP and its extension are examined. Section 3 estimates the WTP due to the declines in mortality rates from 1970 to 2005. Section 4 undertakes two additional analyses: the effects of changes in population size and its compositions; and a trial calculation of the cost-benefit. Finally, Section 6 concludes the chapter.

2. Theoretical Framework

2.1 The Model

I explain the theoretical basis for my estimates based on Becker (2007). While Murphy and Topel (2003, 2006), among others, are cited for the general model used in this case, the simple two-period model as indicated in Becker (2007) is sufficient to explain the essence of their analysis.

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[1] The measurement of the standard of living including life span by "biological measures" was broadly considered by Steckel (2008).

[2] Miyazato (2010) used micro data and estimated VSL at 217 million yen to 264 million yen from the risk premiums with respect to labor accidents. This is almost equal to 280 million yen estimated from industrial data of the labor market by Oka (1999), but considerably smaller than 800 million yen to 1 billion yen estimated by Furukawa and Isozaki (2004) from automobile purchase behaviors.

[3] In addition, the hedonic approach commonly used in utilization of market information is critically examined by Nakajima (2008).

Each person’s life is divided into early life (t=0) and late life (t=1), and his/her utility is modeled as follows:

$$\boldsymbol{U = u_0(x_0, l_0) + BS(h)u_1(x_1, l_1).} \tag{1}$$

Here, the utility for each period depends on goods and services, x_i and leisure l_i, while B is the discount rate (B =1/(1 + β)); S is the rate of those surviving from early life to later life, and is a function of h, health conditions. However, in order to get health condition h, expenditures for health in early life g(h) are required. The result is the following budget constraint:

$$\boldsymbol{x_0 + \frac{Sx_1}{1+r} + g(h) = w_0(1-l_0) + \frac{Sw_1(1-l_1)}{1+r} = W.} \tag{2}$$

The first-order condition (hereinafter FOC) in the utility maximization problem, which maximizes Eq.(1) under Eq.(2), is the following:

$$\boldsymbol{\frac{dS}{dh}Bu_1 = u_{0x}\left(\frac{x_1 - w_1(1-l_1)}{1+r}\frac{dS}{dh} + g'(h)\right).} \tag{3}$$

The left side is the marginal benefit when costs related to health care are increased, and the right side of the equation is marginal cost. The former depends on the future utility level, u_1. In other words, as the income level increases so does u_1, thereby increasing the marginal benefit.

If we substitute another FOC, $u_{0x} = B(1 + r)u_{1x}$ into Eq.(3), we get the following equation:

$$\boldsymbol{\frac{1}{1+r}\frac{dS}{dh}\frac{u_1}{u_{1x}} = \frac{1}{1+r}\frac{dS}{dh}[x_1 - w_1(1-l_1)] + g'(h) = WTP.} \tag{4}$$

The left side of the equation measures the size of the marginal benefit relative to the marginal utility of goods in later life. In other words, this suggests how many units of consumption of goods and services in later life can be given up for marginal improvements in health care, which can be interpreted as the WTP.

Next, assuming homogeneity γ, in the utility function[4], we get the following:

$$\boldsymbol{\frac{u_1}{u_{1x}} = \frac{1}{\gamma}(x_1 + w_1 l_1)\ .} \tag{5}$$

When substituted into Eq.(4), we get the following:

$$\boldsymbol{\frac{1}{1+r}\frac{dS}{dh}\left(\frac{1}{\gamma} - 1\right)(x_1 + w_1 l_1) = g'(h) - \frac{1}{1+r}\frac{dS}{dh}w_1.} \tag{6}$$

Here, if $\gamma = 1$, the left side will be zero[5]. However, because with a normal concave utility function $\gamma < 1$, it will not be zero.

In Eq.(4), if we consider the WTP when $dh = 1$, we get the following:

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[4] Because the utility function u_i (x_i, l_i) is homogenous of degree γ, we get the following (i = 0, 1):

$$\gamma u_i = u_{ix}x_i + u_{il}l_i$$
$$= u_{ix}x_i + (w_i u_{ix})l_i = u_{ix}(x_i + w_i l_i).$$

[5] In this case, Eq.(6) is equal to the FOC derived from maximizing the following net income with respect to h:

$$ny_i \equiv w_0 + \frac{Sw_1}{1+r} - g(h).$$

In Eq.(2), moving $g(h)$ to the right side, we get the following:

$$x_0 + \frac{Sx_1}{1+r} = w_0(1-l_0) + \frac{Sw_1(1-l_1)}{1+r} - g(h).$$

Setting (l_0, l_1) = (0, 0) results in the newly defined variable, ny. Thus, Eq.(6) shows the condition to attain the maximum amount of resources devoted to consumption of goods and services with optimal choice of h.

$$\begin{aligned} \boldsymbol{WTP} &= \frac{1}{1+r} dS \frac{u_1}{u_{1x}} = \frac{1}{1+r} dS \frac{1}{\gamma}(x_1 + w_1 l_1) \\ &= \frac{1}{1+r}(S^1 - S^0)\frac{C_1}{\gamma}. \end{aligned} \tag{7}$$

Here, C_1 is essentially full consumption, which includes not just goods, but leisure in terms of wages as an opportunity cost. When health conditions improve by a unit of 1, the survival rate goes from S^0 to S^1 and, since leisure is enjoyed in addition to goods by those in later life, it is valid to add both together in order to evaluate the merit in terms of full consumption.

2.2 An Extension

This simple two-period model can be easily transformed into a multi-period one. In fact, Murphy and Topel (2003) showed a continuous-time model in this scenario. In order to prepare for estimations in the next section, we first derive the following multi-period equation at discrete times:

$$\boldsymbol{WTP}_{s,a} = \sum_{t=1}^{\infty} \frac{1}{(1+r)^t}\left(\frac{S^2_{s,a+t}}{S^2_{s,a}} - \frac{S^1_{s,a+t}}{S^1_{s,a}}\right)\frac{C_{s,a+t}}{\gamma} \qquad s=m,\ f;\ a=0,1,2,\dots\ , \tag{8}$$

where $WTP_{s,a}$ is the willingness of people, males ($s = m$), and females ($s = f$) of age a to pay when the future survival probability curve shifts from S^1 to S^2, on an individual basis. The overall society WTP is:

$$\boldsymbol{WTP}^{*} = \sum_{s=m,f}\sum_{a=0}^{\infty} \boldsymbol{WTP}_{sa} \cdot \boldsymbol{N}_{sa}\ , \tag{9}$$

where $N_{s,a}$ is the population per sex and per age.

3. Empirical Methodologies

3.1 Data

I compare survival rates for 1970 and 2005, determining the value of improvements in health care conditions during this period with WTP^*. I use a cross section of data (age profile) for 2005 in this forward-looking decision-making estimate of the model. In other words, people of age a in 2005 are assumed to use information available in cross section data such as a survival probability of $a + t$ (t = 1,2, ...). This assumption is required to make up for data that do not span enough time to allow tracking of a full life span.

As explained in detail in Appendix, I calculate the variables used in Eq.(8). The results are summarized in Table 3.1.

Table 3.1 Selected Variables for Each Age Group

Age Group	Consumption Expenditure		Hourly Wages				Leisure Time		Stationary Population				Population	
	National Survey on Family Income and Expeditures		Survey of Wage Structure				Survey on Time Use and Leisure Activities		Life Table				Population Census	
	single/all household, 2004 excluding healthcare 2005 prices, monthly, yen		2004 weighted average of general and pert-time workers 2005 prices, yen				2006 Tertiary Activities hour		for minimum age in each age group				2005 for minimum age in each age group (total for age 100 and over)	
	Male	Female	Males		Females		Male	Female	Males		Females		Male	Female
			regular	incl. overtime and bonus	regular	incl overtime and bonus			2005	difference from 1970	2005	difference from 1970		
0-4									99,764	1,025	99,800	761	539,668	517,132
5-9									99,581	1,564	99,653	1,179	607,278	575,699
10-14							7.18	6.67	99,517	1,760	99,611	1,300	616,199	588,325
15-19			839	862	799	811	7.15	6.58	99,451	1,912	99,571	1,387	632,362	601,812
20-24			1,116	1,258	1,046	1,188	6.72	5.83	99,258	2,271	99,476	1,519	741,422	701,168
25-29	176,399	169,210	1,405	1,694	1,214	1,461	5.97	5.47	98,943	2,593	99,322	1,709	786,273	760,627
30-34	235,728	229,629	1,687	2,075	1,278	1,534	5.55	5.13	98,599	2,948	99,160	1,960	949,205	924,371
35-39			2,022	2,515	1,280	1,526	5.40	5.15	98,187	3,380	98,940	2,257	945,606	926,907
40-44	252,707	246,593	2,253	2,821	1,230	1,447	5.37	5.25	97,607	4,034	98,628	2,659	882,923	870,861
45-49			2,389	2,985	1,202	1,408	5.55	5.55	96,735	4,877	98,177	3,250	774,589	769,944
50-54	203,622	226,292	2,379	2,959	1,179	1,371	5.80	5.67	95,352	5,933	97,481	4,110	816,353	815,028
55-59			2,297	2,808	1,173	1,356	6.08	6.00	93,183	7,469	96,423	5,406	1,043,747	1,060,582
60-64	193,404	216,658	1,633	1,872	1,047	1,155	7.55	6.73	89,839	9,915	94,914	7,424	718,324	752,586
65-69			1,424	1,579	1,036	1,123	8.73	7.02	85,123	14,119	92,831	10,937	763,350	820,761
70-74	219,215	197,961					9.27	7.47	78,367	20,194	89,664	16,447	667,385	762,627
75-79							9.45	7.83	68,058	26,284	84,396	24,848	511,696	645,035
80-84							9.45	8.43	53,598	29,113	75,746	34,692	339,083	519,961
85-89							9.53	9.22	35,609	24,988	61,193	39,645	160,746	354,088
90-94									17,679	14,687	40,453	32,881	64,379	174,451
95-99									5,628	5,178	18,938	17,324	15,942	59,638
100-									969	941	5,202	5,020	3,760	21,593

Consumption in both males and females increases up to age 40 but begins to decrease after age 50. However, the consumption of males in the 70-year-old age bracket increases compared to those at age 60. It seems only natural that consumption would decrease, as it does with females. The reason for the aberration may be a sample bias in the National Survey on Family Income and Expenditures; therefore, before performing the analysis, I adjusted consumption for 70-year-old males to that of the 60-year-old group. The results show that consumption is greater for males up to age 40, but for females beginning at age 50.

In the following, I report regular wages by themselves, and regular wages plus overtime and bonus payments (labeled “including bonus”). For males, a large peak occurs after their mid-40s whereas females peak in their 30s while the height of the peak for females is roughly half that of males. The differences in the profiles are most likely a reflection of the higher percentage of part-time jobs held by females in their mid- and late careers.

Leisure time takes a U-shaped curve across age groups, as we would expect: long hours in young and old ages, but short hours in the 30s and 40s. Moreover, in every age group across the board, males have 5 to 10 percent more leisure time than do females.

The stationary population is the number of people in each age bracket surviving at any point in time when a population of 100,000 people is born. Clearly, this figure is greater for females than it is for males. Compared to 1970, there are 20,000 more males who are 70, 75, and 85 years old, while the number for females increases by 30,000 at ages 80, 85, 90. If we calculate a change in the survival probability rate in Eq.(8), for example, for a period of five years, $S_{s,a+5}^{2005}/S_{s,a}^{2005} - S_{s,a+5}^{1970}/S_{s,a}^{1970}$, males increases by over 20 percentage points in the categories of 75 to 80, 80 to 85, and 85 to 90 years old, and females by over 25 percentage points in the categories of 80 to 85, 85 to 90, and 90 to 95 years old. The change in the survival probability rate is delayed in the life stages for females compared to males, and also occurs to a larger extent.

Finally, the last column shows the population multiplied by per capita WTP. We must take note of the baby-boomer generation (born in 1947 to 49) in 2005 when they reach the latter half of their 50s.

3.2 Results of Estimation

3.2.1 Case 1

Using the variables explained above, I perform the estimation. However, at this point, I must set values of two parameters: the discount rate, roughly the same as the average real, long-term interest rate after the 1990s, $r = 0.03$; and the utility function parameter at $\gamma = 1/3$.

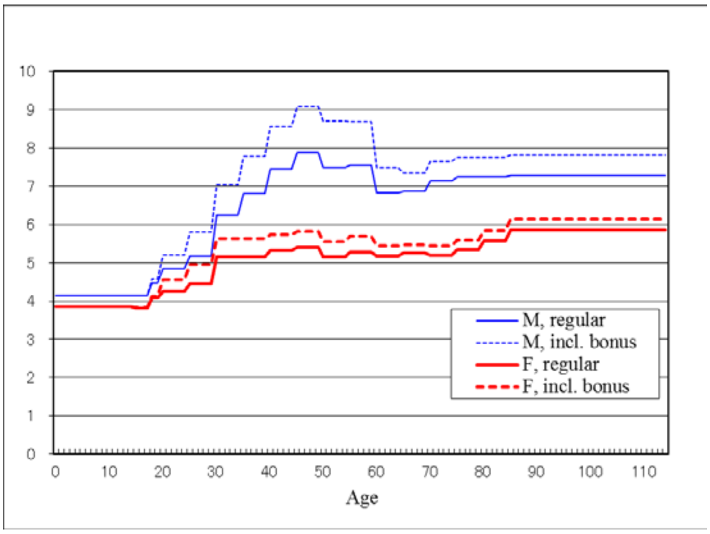
Since not all of the above-mentioned data can be used across all ages from 0 to 114 of the life table, we must decide how to handle the age groups for which data are lacking. As Table 3.1 shows, data for consumption spending, wages, and leisure time are missing in the early and late life age brackets.

Therefore, for Case 1, I insert figures into these age brackets, assuming them to be equal to those available in the closest age brackets. As a result, consumption spending and wages are set constant during age 0 to 15 and age 75 to 114, a rather drastic assumption. This, however, reduces the arbitrariness and makes it easier to understand. We try these assumptions in Case 1.

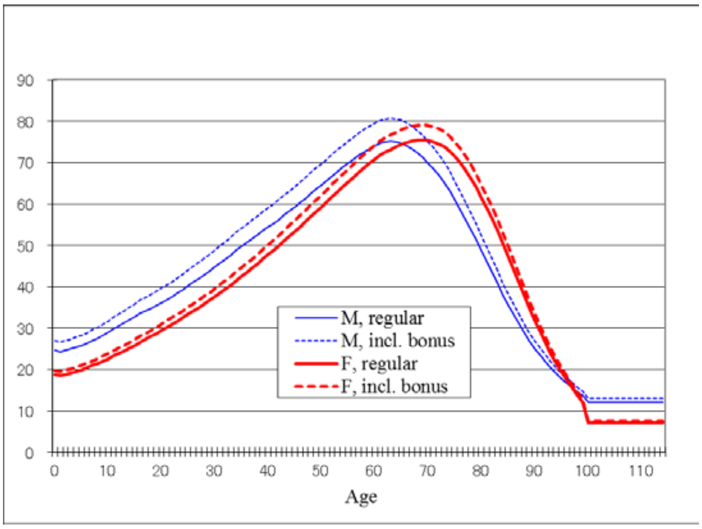
Figure 3.1 (1) shows the results of calculating full consumption C (= $x+wl$) for each sex and age bracket. The peak for males using regular wages was just short of 8 million yen around the late 40s, but when wages with bonus were used, the figure was about 9 million yen. Females reach a peak in their late 40s with another increase of around 6 million yen in later years.

Figure 3.1 Results of Case 1

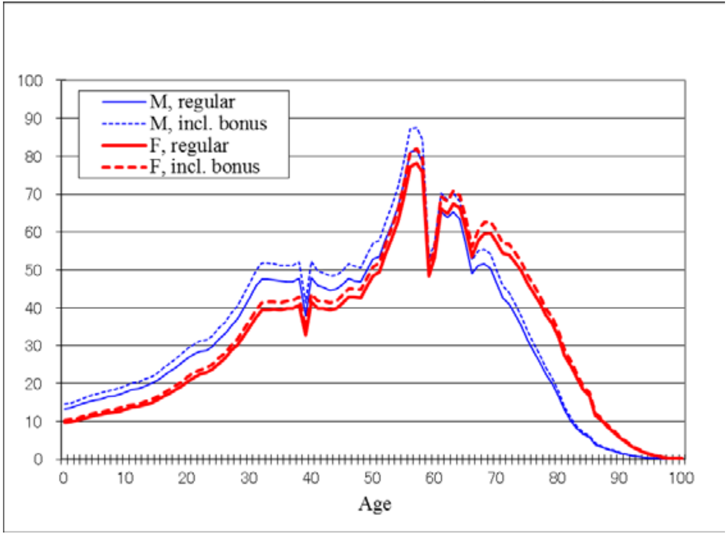
(1) Full Consumption (million yen)



(2) Per Capita WTP (million yen)



(3) WTP for the Entire Economy (million yen)



For this C, using the survival probability rate determined from the stationary population in the life table, we get the WTP per capita from Eq.(8) (Figure 3.1 (2))[6]. For both males and females at regular wages, the peak was around 75 million yen, with males reaching a peak in their early 60s compared to females at around 70. When bonuses are included, both males and female tend to reach a peak around the same time at a level of 80 million yen, males being slightly higher. As can be seen in Figure 3.1 (1) and (2), at full consumption, males consume at a greater level than females, yet when WTP per capita is considered, females are at a higher level than males after age 70, suggesting that improvements in the survival probability rate for females have been more significant, as mentioned earlier.

Figure 3.1 (3) shows the WTP of each age bracket ($WTP_{s,a}$) multiplied by the population. However, since the National Census gives only the total population over 100 years of age, the figures for 100 years and older is the total WTP for the age group of 100 years or older. We can see a WTP peak because of the baby-boomer

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[6] For people over 100 years old, I took the average value. Therefore, the graph shows the average value for all age groups over 100. This is because the *National Census* provides only a total value for ages over 100, as explained later in the article.

generation aged 56 to 58 about 80 trillion yen for regular wages for both males and females. If bonuses are included, the figure is 87 trillion yen for males, and 82 trillion yen for females.

Totaling the WTP for each age group, we get 3,240 trillion yen for males at regular wages and 3,228 trillion yen for females, and a total for both sexes of 6,468 trillion yen. The difference between regular wages and wages including bonuses is only 6 percent. While these figures are the cumulative benefit over 35 years between 1970 and 2005, on an annualized basis, we get 93 trillion yen for males and 92 trillion yen for females, if regular wages are used. When bonuses are included, the figures are 100 trillion yen for males and 97 trillion yen for females. Thus, the total for both sexes amounts to around 200 trillion yen, representing a significant benefit of 40 percent of GDP.

3.2.2 Case 2

In Case 2, I adjust several points to correct the possible overestimation in Case 1. For instance, estimates may be overstated in Case 1 in the following ways: full consumption C, (1) is assumed to be the same during young childhood as in their later teens, and (2) does not decrease in the older years and, in fact, increases. These are the consequences of assuming data for periods where personal consumption spending and wages are missing to be the same as those in the closest age brackets. In Case 2, it is assumed that the younger or older the age is, the less consumption and wages become.

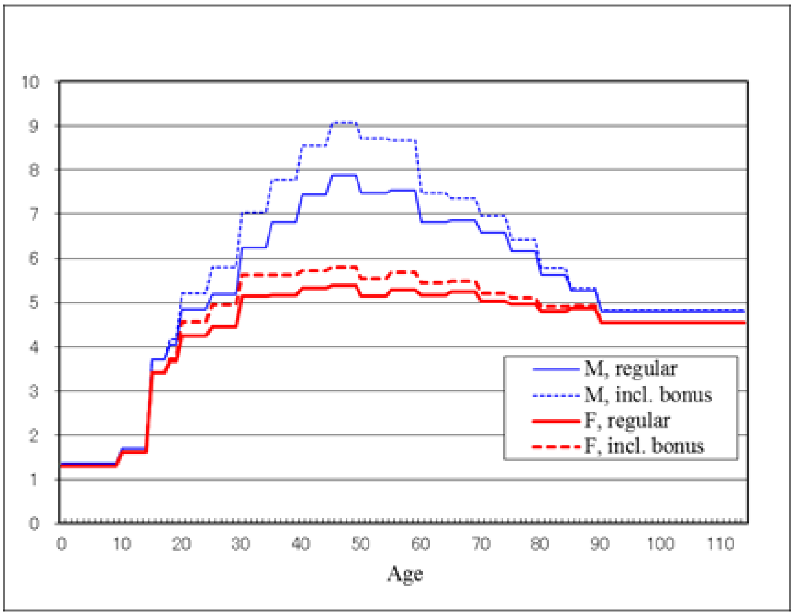
First, pursuant to the terms of the Labor Standards Act, labor is not recognized for people between zero and 15 years old, and their wages are set at zero. The result is that full consumption C of those age 15 and younger will depend on expenditures on goods and services only and, thus, will not be affected by increases or decreases in leisure time. For people older than 70, wages for the 90 and older age group are set the same as for those 17 and younger. To find a new wage profile decreasing from the level of the late 60s to that newly set for those 90 and older, I had to interpolate wages of the four age groups, that is, early and late 70s and early and late 80s. As a result, wages from the late 60s and for the next 20 years were decreased to roughly half for males and 70 percent for females.

Next, consumption expenditures x for up to 30 years old were applied only to people in their early 20s, while I applied 80 percent of the figure for those in their 20s to those in their teens, and again, 80 percent of the figure derived for teens was applied to those from age zero to nine. Similarly, the value for those 70 years old and older was applied only to those in their 70s, and the value for those older than 90 was set the same as for those in their 20s. Finally, to determine the fixed rate of decrease from those in their 70s to 90s and older, I interpolated consumption for those in their 80s who fall between. Therefore, consumption spending was decreased by about 10 percent for males aged 70 to 90 years old, and by about 15 percent for females.

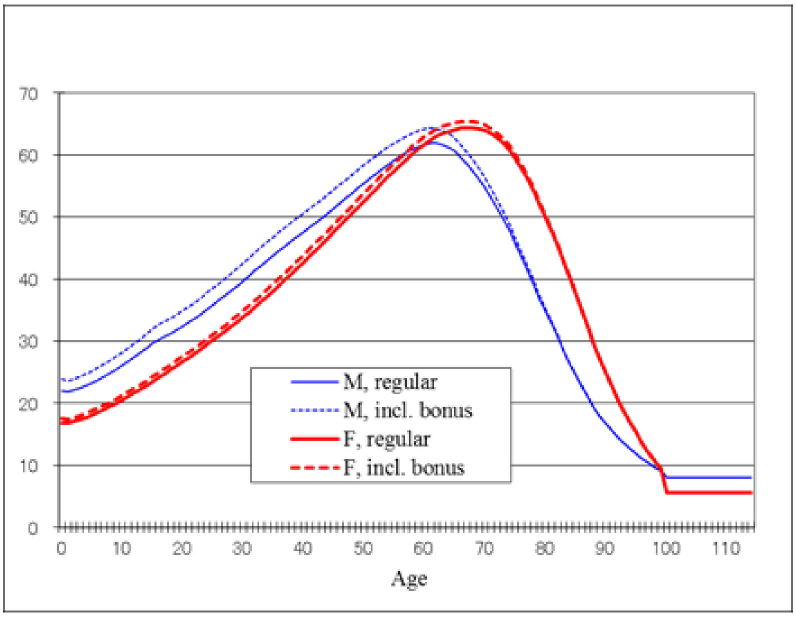
Now, the age profiles for full consumption C, after correcting for the two points above, are redrawn in Figure 3.2 (1). For people 15 years old and younger, C is 1.3 million yen, or about 30 percent of the value in Case 1. In addition, in Case 1, where the early half of the 60s hit a low and then increased, consumption was corrected so that the decrease continues from the 70s onwards. The level for those 90 years old and over is about 4.8 million yen for males and 4.5 million yen for female, roughly 50 to 60 percent and 80 percent lower than their respective peaks achieved in their late 40s.

Figure 3.2 Results of Case 2

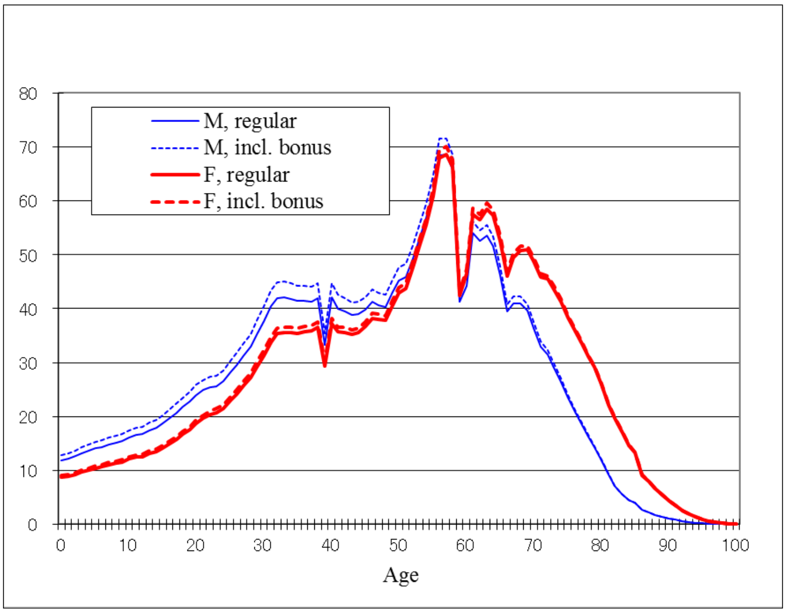
(1) Full Consumption (million yen)



(2) Per Capita WTP (million yen)



(3) WTP for the Entire Economy (million yen)



Using per capita WTP and the corrected full consumption, we see in Figure 3.2 (2) that wages for males peak at around 60 years old at 61 million yen for regular wages and 64 million yen when a bonus is included. The peak for females occurs in their late 60s with both wages ranging from about 64 to 65 million yen. Compared to Figure 3.1 (2), the downward shift is smaller for females. The reversal of per capita WTP for males and females goes from the mid-60s in Case 1 to the late 50s in this instance.

Figure 3.2 (3) shows that when the WTP is multiplied by the number of people, the peak is again located with the baby-boomers in their late 50s. However, the height of the peak for regular wages shows a decrease of about 12 trillion yen compared to Case 1, to 68 trillion yen for each of males and females. For wages including bonuses, the figure decreases 16 trillion yen to 71 trillion yen for males, and 12 trillion yen to 70 trillion yen for females.

For the entire economy, using regular wages for males, we get 2,742 trillion yen, and 2,817 trillion yen for females for a total of 5,559 trillion yen. Wages including bonuses yields 2,889 trillion yen for males and 2,877 trillion yen for females, amounting to 5,766 trillion yen in total. As in Case 1, I convert this to an annual basis, arriving at 159 trillion yen for regular wages (78 trillion yen for males and 80 trillion yen for females) and 165 trillion yen for wages including bonuses (83 trillion yen for males and 82 trillion yen for females). The results of Case 1 and Case 2 are summarized in Table 3.2. The results of the estimates performed in Case 2 are approximately 85 percent of their Case 1 counterparts.

Table 3.2 Comparison between Case 1 and Case 2

Trillion yen

			Male	Female	Total
Case 1					
	Regular Wages	total for 1970-2005	3,240	3,228	6,468
		annualized as to 2005	93	92	185
	Incl. overtime and bonus	total for 1970-2005	3,507	3,387	6,894
		annualized as to 2005	100	97	197
Case 2					
	Regular Wages	total for 1970-2005	2,742	2,817	5,559
		annualized as to 2005	78	80	159
	Incl. overtime and bonus	total for 1970-2005	2,889	2,877	5,766
		annualized as to 2005	83	82	165

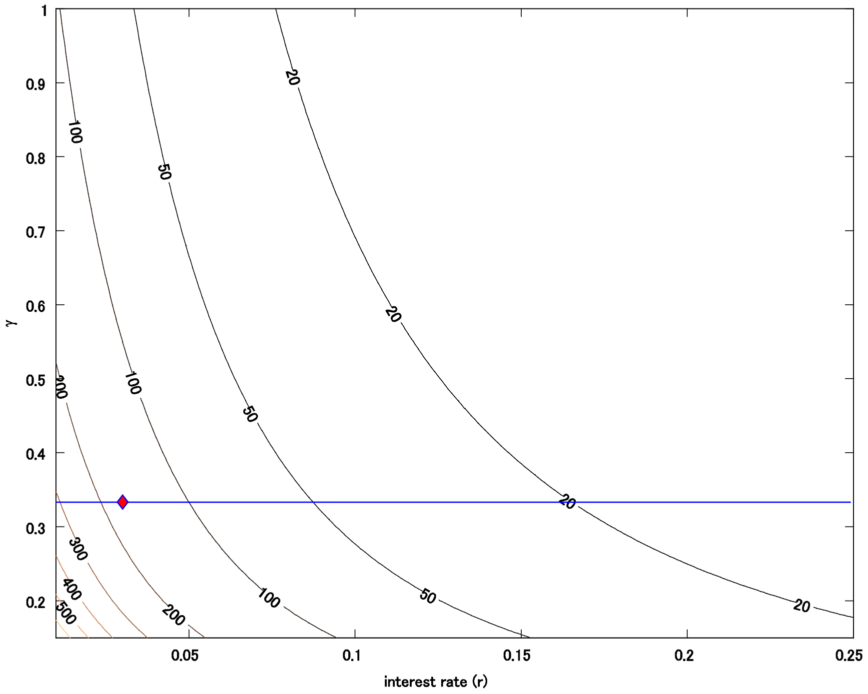
As shown above, the reason why WTP of females at regular wages is larger is thought to be that the effects of long average life expectancy of females exceeded the effects of low wages. On the other hand, it is thought that the effects of higher wages including bonuses of males exceeded the effects of shorter average life span resulting in higher WTP of males.

3.3 Re-examining Parameters

We now re-examine how robust the results obtained in the preceding section are. In the estimate, two parameters remained fixed. One is the interest rate r equal to the real, long-term rate of 3 percent. A higher interest rate would discount more heavily the outcome of future improvements in the survival probability rate, thereby reducing the WTP for the overall economy, WTP^*. The other parameter is γ in the utility function, which is set at 1/3. In Eq.(8), it is clear that γ acts as a scale parameter, and, if it doubles, WTP^* will be halved.

Figure 3.3 Combination of (r, γ) and WTP*

(annualized, trillion yen)

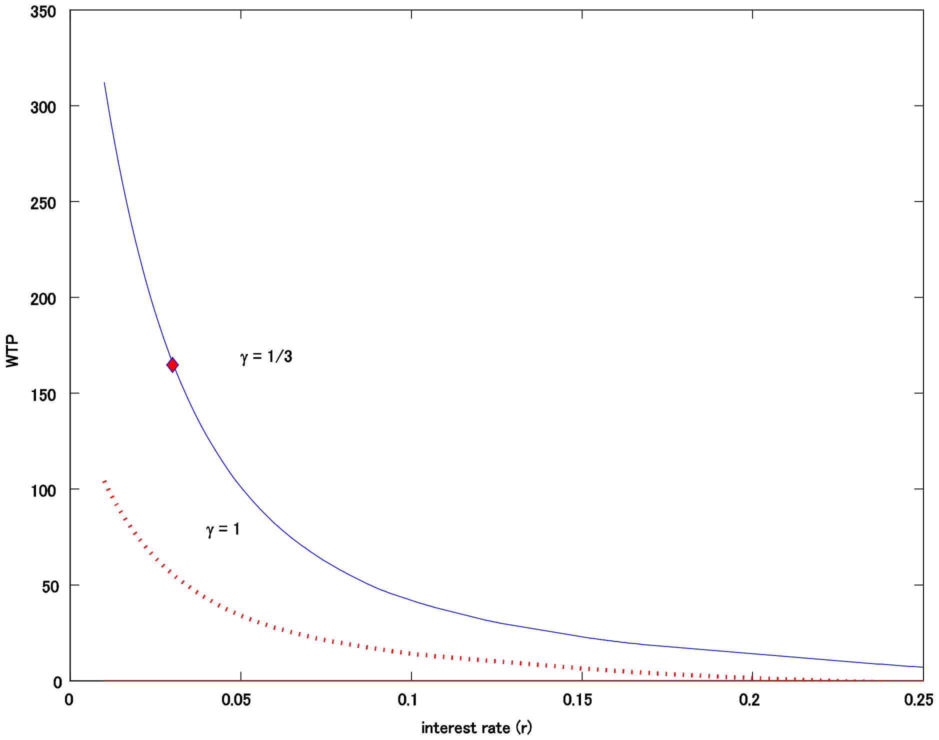


Now, let us see how WTP^* changes in response to changes in the values for these parameters (r, γ). Figure 3.3 shows WTP^* as contour lines on the plane $r-\gamma$. Moving close to the origin on the plane will obtain a higher WTP* value. Note the WTP* values are calculated from the wages including bonuses and are converted to an annual basis. From this figure we can see what combinations of parameters would produce results similar to what we obtained in the preceding section (shown as ◊ in Figure 3.3).

To see in more detail how WTP^* changes, the line in Figure 3.4 is a cross section of Figure 3.3 cut by the straight line $\gamma = 1/3$. Further, the dotted line in Figure 3.4 is the upper limit of Figure 3.3, that is, cut by $\gamma = 1$. The dotted line is equivalent to the lower limit when γ becomes larger causing the solid line to shift downward. On the other hand, when γ becomes smaller, the solid line will shift upward.

Figure 3.4 WTP* as a Function of *r* (given γ = 1/3 and 1)

(annualized, trillion yen)

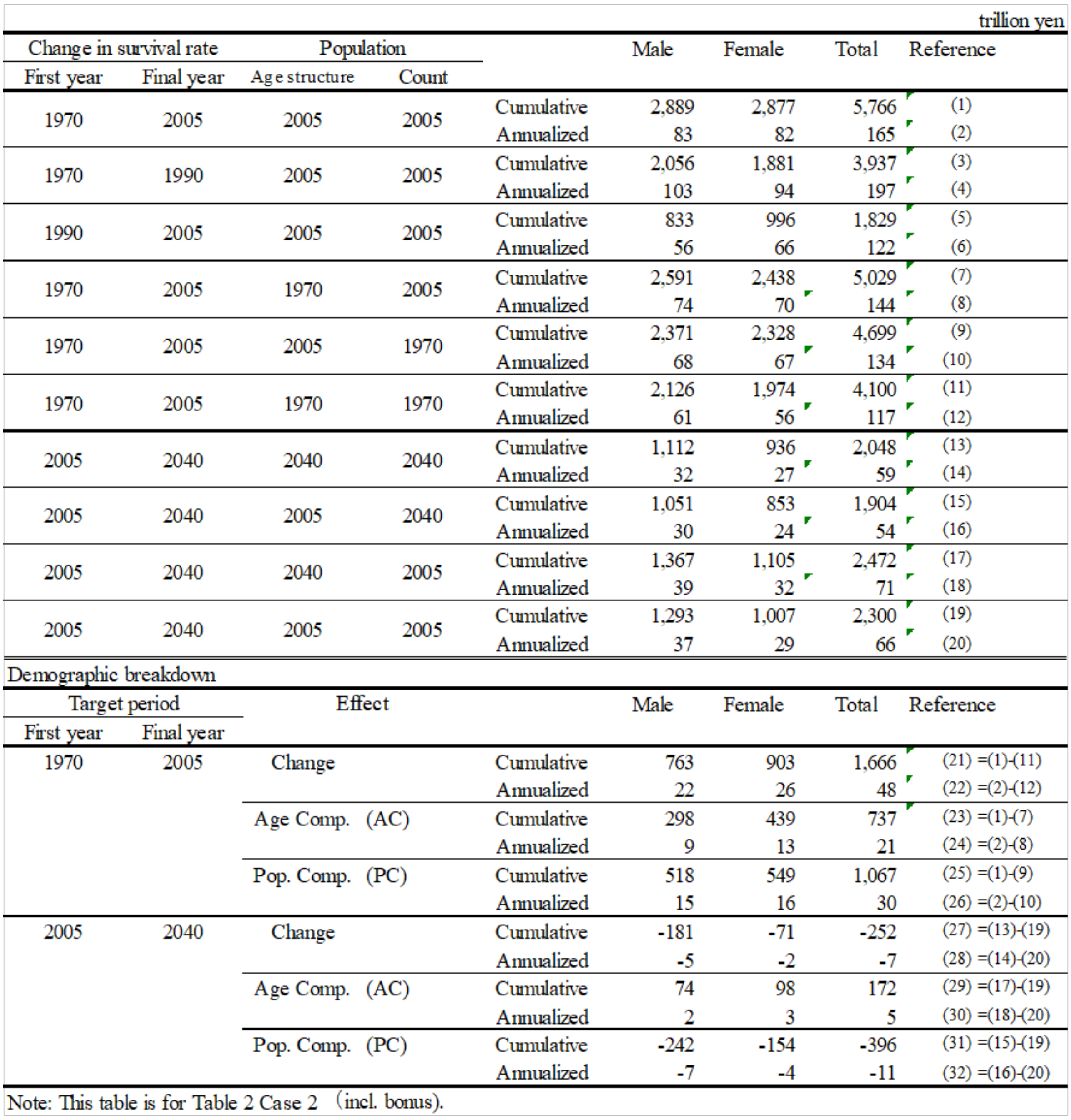


3.4 Changes by Period

Up to this point, I have discussed and estimated the change in the survival rate from 1970 to 2005 (S^{2005} – S^{1970}). Now, I divide this time frame into two separate periods, 1970 to 1990 and 1990 to 2005, in order to determine the WTP for each one separately. However, because I use the full consumption and population for 2005, there will be differences in survival rate changes, causing differences in the size of WTP from S^{1990} – S^{1970} and S^{2005} – S^{1990} only.

The results of these calculations are shown in Table 3.3, lines (3) − (6) [see Ref. column of the table]. On an annual basis, the change occurring in the first 20-year period is greater: about 70 percent of all the WTP occurred in the period spanning just short of 60 percent (= 20/35) of the entire period. Furthermore, it is interesting to observe that in the first 20-year period, the change in survival rate makes the value for males greater, while for the next 15 years, it is higher for females. This is because females have a larger population in their elderly years, with a significant rise in survival rate.

Table 3.3 Summary and Comparison of Results



trillion yen

Change in survival rate		Population			Male	Female	Total	Reference
First year	Final year	Age structure	Count					
1970	2005	2005	2005	Cumulative	2,889	2,877	5,766	(1)
				Annualized	83	82	165	(2)
1970	1990	2005	2005	Cumulative	2,056	1,881	3,937	(3)
				Annualized	103	94	197	(4)
1990	2005	2005	2005	Cumulative	833	996	1,829	(5)
				Annualized	56	66	122	(6)
1970	2005	1970	2005	Cumulative	2,591	2,438	5,029	(7)
				Annualized	74	70	144	(8)
1970	2005	2005	1970	Cumulative	2,371	2,328	4,699	(9)
				Annualized	68	67	134	(10)
1970	2005	1970	1970	Cumulative	2,126	1,974	4,100	(11)
				Annualized	61	56	117	(12)
2005	2040	2040	2040	Cumulative	1,112	936	2,048	(13)
				Annualized	32	27	59	(14)
2005	2040	2005	2040	Cumulative	1,051	853	1,904	(15)
				Annualized	30	24	54	(16)
2005	2040	2040	2005	Cumulative	1,367	1,105	2,472	(17)
				Annualized	39	32	71	(18)
2005	2040	2005	2005	Cumulative	1,293	1,007	2,300	(19)
				Annualized	37	29	66	(20)

Demographic breakdown

Target period		Effect		Male	Female	Total	Reference
First year	Final year						
1970	2005	Change	Cumulative	763	903	1,666	(21) =(1)-(11)
			Annualized	22	26	48	(22) =(2)-(12)
		Age Comp. (AC)	Cumulative	298	439	737	(23) =(1)-(7)
			Annualized	9	13	21	(24) =(2)-(8)
		Pop. Comp. (PC)	Cumulative	518	549	1,067	(25) =(1)-(9)
			Annualized	15	16	30	(26) =(2)-(10)
2005	2040	Change	Cumulative	-181	-71	-252	(27) =(13)-(19)
			Annualized	-5	-2	-7	(28) =(14)-(20)
		Age Comp. (AC)	Cumulative	74	98	172	(29) =(17)-(19)
			Annualized	2	3	5	(30) =(18)-(20)
		Pop. Comp. (PC)	Cumulative	-242	-154	-396	(31) =(15)-(19)
			Annualized	-7	-4	-11	(32) =(16)-(20)

Note: This table is for Table 2 Case 2 （incl. bonus).

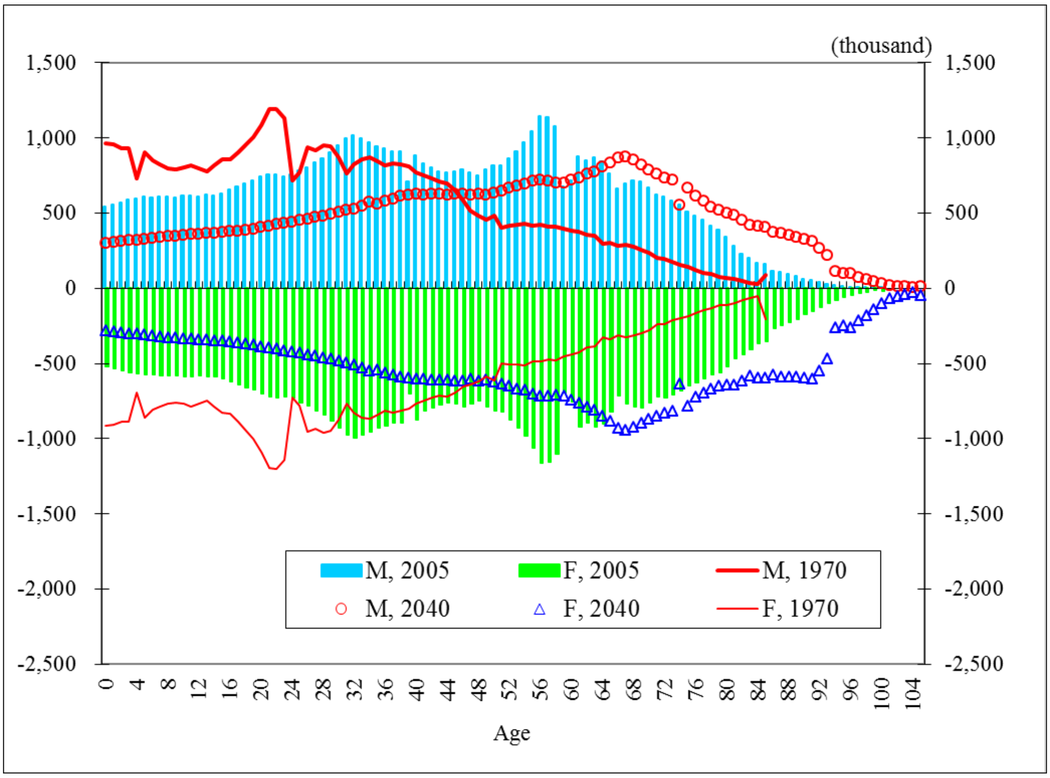
4. Further Analysis

4.1 Aspects of Changes in Population

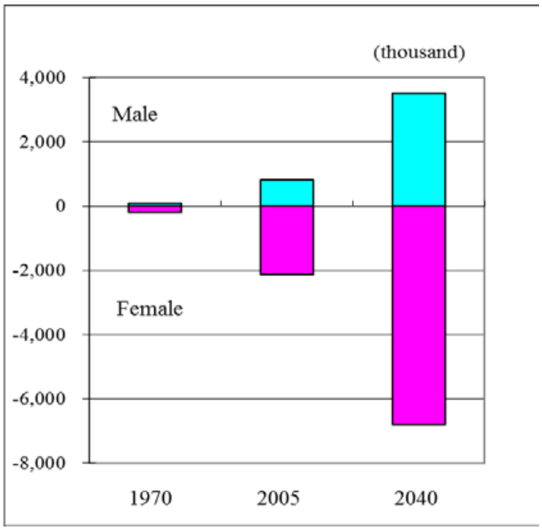
Note that the WTP for the entire economy is obtained as the sum of per capita WTP ($WTP_{s,a}$) multiplied by population per sex and age group in Eq.(9). In the actual calculations above, we used the population as of 2005, that is, $N_{s,a} = N_{s,a}^{2005}$. Therefore, if we were to use the population in 1970, $N_{s,a} = N_{s,a}^{1970}$, the results for WTP^{*} will naturally be different.

Figure 4.1 Population in 1970, 2005, and 2040.

(1) Male and Female Population by Age



(2) Population aged 85 and over by sex



In fact, the size of the population and the age structure vary significantly between the two periods. First, the population of 104 million in 1970 increased to 127 million in 2005, for a 22.7 percent increase. When viewed by sex, the population of males increased 21.9 percent, while that of females grew at a greater rate of 23.5 percent.

Next, the birthrate continues to fall and the aging population gets underway significantly between these two periods. If we consider the population pyramid[7] for Figure 4.1(1) for both periods, we see that the population

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[7] Looking at Ta 4.1(1), below the left axis, a bar graph for 2005, and a line graph for 1970, respectively, shows the population pyramid.

up to age 29 for both males and females is lower in 2005, and greater for ages 30 and older. The difference accounts for more than 30,000 people per age group from 50 to 70 years old for males and 50 to 80 years old for females. What is even more indicative of aging is the increases in the population older than 85. On the graph line showing 1970, there is a curious increase at age 85 because the population is not divided into age groups after 85, instead giving the total of people older than that age. However, Figure 4.1(2), which shows the population of males and females older than 85, reveals that males have increased from 89,000 to 811,000, while females have increased from 207,000 to 2,116,000, a nine- and tenfold increase, respectively.

An increase in population in conjunction with the changes in age structure from 1970 to 2005 will boost WTP^*. Eq.(9) clearly demonstrates that as the population increases, WTP^* increases proportionally. Furthermore, the younger population with a smaller per capita WTP decreases, as shown in Figure 3.2(2), while the older population with a greater WTP increases, causing the balance to shift to a greater WTP^*.

Now, turn to a quantitative analysis of demographic impacts on WTP^*. Specifically, how will WTP^* change if we use 1970, $N_{s,a}^{2005}$, instead of $N_{s,a}^{1970}$, and how do the increase in population and the changes in the age structure between those years contribute to its changes? First, the following must be defined:

$$\boldsymbol{WTP^* = \sum_s \sum_a WTP_{s,a} \cdot N_{s,a}^{2005} = \sum_s \sum_a WTP_{s,a}(\alpha_{s,a}^{2005} \cdot N_{s,\cdot}^{2005})}, \tag{10}$$

$$\boldsymbol{WTP' \equiv \sum_s \sum_a WTP_{s,a}\left(\alpha_{s,a}^{1970} \cdot N_{s,\cdot}^{2005}\right)}, \quad \boldsymbol{N_{s,\cdot}^{2005} \equiv \sum_a N_{s,a}^{2005}}, \tag{11}$$

$$\boldsymbol{WTP'' \equiv \sum_s \sum_a WTP_{s,a}\left(\alpha_{s,a}^{2005} \cdot N_{s,\cdot}^{1970}\right)}, \tag{12}$$

$$\boldsymbol{WTP^{1970} \equiv \sum_s \sum_a WTP_{s,a}\left(\alpha_{s,a}^{1970} \cdot N_{s,\cdot}^{1970}\right)}. \tag{13}$$

Then, we get the outcome of the population increase (*PC*) and the change in age structure (*AC*) from the following, respectively:

$$\boldsymbol{\Delta \mathrm{WTP} = WTP^* - WTP^{1970}} \tag{14}$$

$$\boldsymbol{= \underbrace{WTP^* - WTP'}_{AC} + WTP' - WTP^{1970}} \tag{15}$$

$$\boldsymbol{= \underbrace{WTP^* - WTP''}_{PC} + WTP'' - WTP^{1970}}. \tag{16}$$

The results of the above calculations are shown in Table 3.3, lines (21)-(26) [see Ref. column of the table]. Replacing $N_{s,a}^{1970}$ by $N_{s,a}^{2005}$ decreases the WTP by 1,666 trillion yen or roughly 30 percent. The decrease for females is approximately 20 percent more than that of males: *AC* has a greater impact on females, whereas there is little difference in *PC* between males and females. However, note that *PC* does have a greater overall effect than *AC*, accounting for two-thirds of ΔWTP for males and 60 percent for females. The total of males and females yields 737 trillion yen for *AC* and 1,067 trillion yen for *PC*.

4.2 Estimating Future *WTP* based on a Demographic Projection

Based on the foregoing analysis, we can consider the future trends in WTP^*. It is not an easy task to predict a future path of per capita *WTP* ($WTP_{s,a}$). However, if we hold it constant and use future demographics, we can get an idea of the general trend.

Because the period in my analysis included the 35 years up to 2005, I now estimate the same analysis for another 35 years, from 2005 to 2040. The following insights are gained from a brief look at the medium case of the demographic projections provided by the National Institute of Population and Social Security Research. First, the trend toward fewer children and greater aging is likely to increase AC, thereby pushing the entire economy WTP in a positive direction. Second, we can expect the pace of improvements in survival rates to slow down if we look at trends in average life expectancy.[8] Finally, in 2040, the population will decrease to 106 million, on a par with 1970 levels at 104 million people.[9] Therefore, PC will cause the WTP of the entire economy to shrink. Taking into account these conflicting forces, we can expect the WTP in the next 35 years to be less than it was in the past 35 years.

Actually, we estimate the WTP to be 2,048 trillion yen in 2040 (Table 3.3, line 13), which is just over a third of the WTP for the past 35 years. If, instead, we calculate using the 2005 population and age structure, which may be justified if this is regarded as decision as of 2005, the *WTP* turns out to be 2,300 trillion yen (Table 3.3, line 19), or about 10 percent greater, and still near 40 percent of the 35-year preceding level. The 60 percent decrease reflects a decrease in improvements to survival rates. *AC* may increase *WTP* by 7 percent to 2,472 trillion yen, while *PC* may decrease it by 17 percent to 1,904 trillion yen. The decrease for males will be approximately 2.5 times that for females because, not only is the decrease due to male *PC* greater than that for females, the increase from *AC* is less significant than it is for females.

5 Aspects of Cost-Benefit

5.1 Determining Net WTP

Performing a cost-benefit analysis needs to determine cost. Cost refers to the necessary expenditures to improve health conditions h by one unit of measure, $dg = g'(h)$. This study has not considered the cost, and therefore, the *WTP* obtained is in gross terms. However, to think of WTP in net terms, we subtract costs and express it using the two-period model used in Section 2.1[10]:

$$\boldsymbol{WTP^{*N} = WTP^{*} - dg.} \qquad (17)$$

Cost in the multi-period model is:

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[8] At age 0, the average life expectancy increases between 1970 and 2005 by 9.25 years for males (=78.56−69.31) and 10.86 years for females (=85.52−74.66), but the corresponding figures from 2005 to 2040 will be 4.15 years (= 82.71−78.56) and 3.91 years (=89.43−85.52), respectively. The same picture is drawn for life expectancy at age 65. From 1970 to 2005, the margin was 5.63 years (= 18.13−12.50) and 7.85 years (=23.19−15.34) for males and females, respectively, which translates in the next 35 years to 3.19 years (=21.32−18.13) and 3.32 years (=26.51−23.19), respectively.

[9] Comparing population estimates as of as of October 1 in various years, as published by Statistics Bureau, Ministry of Internal Affairs and Communications, the population of Japan peaked in 2004. Therefore, in terms of the size of the population, *WTP* would be greatest in 2005, the year used in this estimate.

[10] More specifically, because Eq. (7) can be transformed as follows, its first term on the right side corresponds to the net WTP:

$$WTP = \frac{1}{1+\gamma}(S^1 - S^0)(c_1 - w_1) + g'(h)$$

$$\boldsymbol{dg = \sum_{a=0}^{\infty} dg_a . N_a,} \tag{18}$$

$$\boldsymbol{dg_a = \sum_{t=0}^{\infty} \frac{1}{(1+r)^t} . S_a^2 . d\tilde{g}_{a+t} .} \tag{19}$$

This is the discounted present value of change $d\tilde{g}_a (= \tilde{g}_a^2 - \tilde{g}_a^1)$ in health-related expenditures per age group $\tilde{g}_a$, to get the value with survival rate S^2 after the change.[11]

5.2 Differences with Approach Based on Health Capital

In addition to an approach based on *WTP*, another possible approach to measure benefits of health care is based on Grossman's (1972) health capital. A representative example of the latter's approach is Cutler and Richardson (1998, 1999). Here, we first outline their method by using the two-period model mentioned in Chapter 2. Next, we summarize the differences with the approach based on *WTP* stated above.

We suppose that health-care expenditures of early life ($t = 0$) and late life ($t = 1$) are m_t. Under the survival rate S, the discounted present value of health-care expenditures, *PDVMS*, can be shown as follows:

$$\boldsymbol{PDVMS = m_0 + \frac{Sm_1}{1+r}.} \tag{20}$$

On the other hand, H (health capital) is defined as follows:

$$\boldsymbol{H \equiv V \times \left[Q_0 + \frac{SQ_1}{1+r}\right].} \tag{21}$$

Here, V shows a value of a "perfect health" condition for each period. Q_t is quality-of-life, and there are two approaches to calculate Q_t as follows:

- YOL (years-of-life) approach: if surviving, $Q_t = 1$, and if dead, $Q_t = 0$; and
- QALY (quality-adjusted life year) approach: $0 \leq Q_t \leq 1$ between death (0) and "perfect health" (1).

Then, if the survival rate changes from S^1 to S^2 due to an increase in health-care expenditures, *dPDVMS*, and Q_t also changes to Q'_t (t =0,1), the increase in health capital H is:

$$\boldsymbol{dH = V \times \left[Q'_0 - Q_0 + \frac{1}{1+r}(S^2 Q'_1 - S^1 Q_1)\right]} \tag{22}$$

$$\boldsymbol{= V \times \left[\frac{1}{1+r}(S^2 - S^1) Q_1\right], \qquad if\ Q'_t = Q_t.} \tag{23}$$

After respective calculation of costs and benefits as shown above, the cost-benefit analysis first calculates *ER* (effective ratio) as follows:

$$\boldsymbol{ER = \frac{dPDVMS}{dH}.} \tag{24}$$

This approach assumes that an increase in (the present discount value of) health-care expenditures contributes to an increase in health capital only by the ratio b ($b\Delta H = \Delta PDVMS$). Health-care expenditures are, therefore,

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[11] Note there is no subscript s in the equation, unlike in Section 2. Per capita national medical care expenditures are published for each age group, but not by sex, which disallows the calculation employed for benefit by sex and age group to get a total.

effective in the case of $b > ER$. In other words, because ER gives a lower limit for the determination of whether health-care expenditures are effective or not, the lower it is, the higher the possibility that health care is effective is.

Then, what kind of relationship does the approach stated above have with the model mentioned in Section 2.1? At first, let us compare Eq.(7) with Eq.(22). If, in Eq.(22), (a) when the increase in health-care expenditures, $dPDVMS$, does not affect Q_t, but affects only the survival rate S, and (b) when QOL in period 1 shown by $V \times Q_1$ is equal to the utility level in period 1, $u_1/u_{1x}= C_1/\gamma$ (measured by consumption of goods), Eq.(22) is equivalent to Eq,(7). Therefore, WTP and the increase of health capital, dH, are equal.

In addition, as to the costs, we get the following from Eq.(20):

$$\boldsymbol{dPDVMS = dm_0 + \frac{1}{1+r}(dS \cdot m_1 + S \cdot dm_1)}. \tag{25}$$

Therefore, (c) when $dm_0 = 0$, and (d) when S is evaluated based on S^2, Eq.(25) is equivalent to Eq.(19).

Let us examine these conditions (a)-(d). The health-related expenditures g are expended in period 0, but they do not affect the utility in the period because of their nature of capital expenditures, and affect only the survival rate. In contrast, the health-care expenditures m_t in Eq.(20) are not subject to such constraints and may affect both the utility in the same period and quality of life. The conditions of (a) and (c) are related to the difference in nature between g and m. In addition, the condition of (b) is thought to be intended to adjust a “level,” because V shows a measure of perfect health condition. Accordingly, from Eqs.(7) and (23), we get the following:

$$\boldsymbol{dH = \left(\frac{VQ_1}{C_1/y}\right) WTP = \mu WTP}. \tag{26}$$

Thus, if the health value (VQ_1) in period 1 is equal to the utility (measured using goods as a numeraire) in the period ($\mu = 1$), they are equal.

5.3 Estimate

I use the WTP (Case 2, wages including bonuses) in Section 3.2.2 as the benefit to perform a cost-benefit analysis. I use the ***National Medical Care Expenditures*** published annually by the Ministry of Health, Labor, and Welfare as a major source of information on costs. These expenditures are defined as “all expenditures for treatment necessary for accident or illness,” which leaves out some of the cost for health-care conditions, such as pregnancy or immunizations, thus resulting in a narrower target.[12] In this model, however, with respect to measuring the benefit of increased survival rates, it is possible that our target is too wide if we consider only the costs that directly contribute to the increase in survival rates. We must also be cognizant that introducing a system of long-term care insurance caused a shift in expenditure level in FY 2000.

The National Medical Care Expenditures were 2 trillion yen in 1970 and increased to 33 trillion yen in 2005. To calculate the costs using Eq.(18) and (19), we need per capita expenditure by age, which the Ministry of

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[12] National medical care costs include expenditures for medical and dental treatments, pharmacy dispensing expenditures, food and living care expenditures during hospitalization, and home-visit nursing care expenditures, as well as other costs such as transportation for medical purposes covered by health insurance. On the other hand, as they are limited to treatments for diseases and injuries, they exclude the following: (1) costs for normal pregnancies and deliveries; (2) costs for medical check-ups and immunizations to maintain and enhance health; and (3) costs for prosthetic devices for eyes and limbs, etc. required for established physical disabilities. Furthermore, they also exclude extra charges for hospitalization and dentistry, which are not covered by health insurance. The explanation stated above is provided on the website of the Ministry of Health, Labor, and Welfare.

Health, Labor, and Welfare has tracked only since 1997. The general medical care expenditures, its largest component, has information on a per capita per age group basis, but unfortunately only after 1977.[13] Table 5.1 summarizes the available data, and I fill in blanks with estimates (shown in *italic*).[14] These estimates in 1970 are used for the cost calculation after being converted to 2005 figures using the consumer price index (total).

Now, let us calculate the costs. The cumulative total for 1970 to 2005 is 548 trillion yen, and 16 trillion yen on an annual basis, as shown in the left columns in Table 5.2. Of the 35 years, the first 20 years annualized are 22 trillion yen, and the next 15 years annualized are 7 trillion yen. Thus, the first period saw costs increase at a rate of almost three times that of the second period. Next, I turn to the benefit. Using the benefit as determined from wages including bonuses, the net benefit, on a cumulative basis from 1970 to 2005, is 5,218 trillion yen, or approximately 90 percent of gross benefit. In other words, the cost-benefit ratio (B/C) is 10.5. The ratio for the 20 years up to 1990 is 8.8, and increases in the following 15 years after 1990 to 17.5.

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[13] The national expenditure for health care in 2005 (\33.1 trillion) is the total of general medical exam and treatment costs (\24.9 trillion), dental treatment (\2.6 trillion), pharmacy dispensing costs (\4.6 trillion), food and living care expenditures during hospitalization (\1.0 trillion), and home-visit nursing care (\0.04 trillion). General medical exam and treatment costs include hospitalizations (\12.1 trillion) and outpatient care (\12.8 trillion).

[14] Specifically, based on the published 1997 data of national medical care expenditures and general medical care expenditures, both of which are on per capita and age group, I estimated 1990 figures of the former, using the latter's counterparts and other available information in 1990. Once done with the estimates for 1990, based on this result, I applied the same method to obtain the 1977 estimates. For 1970, I estimated expenditures by age group, using the 1977 estimates and less, but still available information in 1970, such as the total amount of national medical expenditures, and total population and its age components.

Table 5.1 Trends in per Capita National Medical Care Expenditures by Age

	Fiscal year				
Age group	2005	1997	1990	1977	1970
	National medical care expenditures (A), ¥1,000				
0 － 14	129.5	93.3	*58.6*	*30.2*	*10.2*
15 － 44	103.5	94.5	*82.1*	*55.2*	*18.6*
45 － 64	250.9	245.2	*205.4*	*108.7*	*36.6*
65 － 69	444.8	453.9	*368.3*	*172.3*	*58.1*
70 and over	742.3	802.0	*655.0*	*272.3*	*91.8*
average	259.3	229.2	*166.7*	*75.1*	*24.1*
（ref） total （trillion yen）	33.1	28.9	20.6	8.6	2.5
	General medical care expenditures (B), ¥1,000				
0 － 14	94.2	74.4	51.4	27.7	
15 － 44	71.6	70.2	67.1	47.1	
45 － 64	183.7	195.4	180.2	99.5	
65 － 69	332.6	377.3	336.9	164.5	
70 and over	595.6	650.4	584.4	253.6	
average	196.2	182.6	145.4	67.6	
（ref） total （trillion yen）	25.0	23.0	18.0	7.7	
	ratio (=B/A), per cent				
0 － 14	72.7	79.7	87.7	91.6	
15 － 44	69.2	74.3	81.7	85.3	
45 － 64	73.2	79.7	87.7	91.6	
65 － 69	74.8	83.1	91.5	95.5	
70 and over	80.2	81.1	89.2	93.2	
average	75.6	79.7	87.2	90.0	

Note: Figures in *italics* are author's estiates.

Table 5.2 Results from Estimating Cost and Benefit

trillion yen

Period		Cost (C)	Benefit (B)	Net Benefit (=C-B)
1970-2005	Cumulative	548	5,766	5,218
	Annualized	16	165	149
1970-1990	Cumulative	449	3,937	3,488
	Annualized	22	197	174
1990-2005	Cumulative	99	1,829	1,730
	Annualized	7	122	115

Note: Benefits are the same for Table 3.3, Line (1)-(6).

Fukui and Iwamoto (2004) estimate ER at 18-28% in YOL and 24-30% in QALY in Eq. (24) using data of 1990-1999[15]. In our estimate results, the calculation of ER by considering *WTP* and the costs required for it as *dH* and *dPDVMS* respectively results in ER of 9.5%, which is lower than that in Fukui and Iwamoto (2004). One reason for that is thought to be, for example, the difference in the concept of costs as stated above.

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[15] In addition, Cutler and Richardson (1999) estimate ER in the United States from 1950 to 1990 at approximately 30%.

Murphy and Topel (2003) treat net benefit, WTP^N, as a Solow residual and think it depends on an increase in knowledge regarding health care. They go on to compare it with investments in health-care research and development. In Japan, annual data on investment in research and development are available from the ***Survey of Research and Development*** by the Ministry of Internal Affairs and Communications, although they are classified into only broadly defined sectors. Just for reference, let us use the total expenditures for research and development. The cumulative sum from 1970 to 2005 (adjusted for inflation and real 3 percent interest rate) was 565 trillion yen, which corresponds to 16 trillion yen per year, or less than 10 percent of WTP^N.

5.4 Reexamination

Before interpreting the results of the cost-benefit analysis shown above, let us examine each of costs and benefits again. First, we need to note that benefits are observed only in terms of extension of life span. As mentioned in Section 5.2, because improvements in quality of life such as removal of pain are not considered, it is a definition which is too narrow for benefits of health care. In other words, it is necessary to consider health care not only from the aspect of investment but also from that of consumption.

Next, as to costs, we need to note that the outcome of extension of life span is affected by various environmental factors other than health care. For example, there are various possible factors including improvements in public sanitation and diets, spread of knowledge on health, and fulfillment of social security systems (other than health care). Therefore, it is extremely difficult to determine the scope of costs corresponding to benefits and evaluate them.

According to this line of thinking, there is still much room for improvement in the cost-benefit analysis shown in this paper. On the other hand, in order to make it easier to grasp the correspondence between costs and benefits, we can conduct an analysis, for example, by disease or by medical care, but an excessive pursuit of specificity tends to result in an analysis without macroeconomic implications which is, so to speak, “missing the forest for the trees.” In particular, when considering health and medical care in a cross-sectional comparison of various fields including continuous growth and fiscal consolidation, it is greatly beneficial to have macroscopic implications. In the light of the significance in this context, it is a future agenda to make realistic analyses of health care, without losing sight of macroscopic implications, and from a broad angle.

6. Conclusion

In this chapter, I attempted to quantify the value of the decrease in the mortality rate of Japanese citizens from 1970 to 2005 using the WTP in accordance with Murphy and Topel (2003, 2006). The results of these estimates were about 5,800 trillion yen on a cumulative basis for the 35-year period, and 165 trillion yen when annualized as of 2005. Unfortunately, because all the data for sex and age group necessary to perform this estimate were not available in official statistics, I was compelled to make arbitrary assumptions with regard to consumption at young and very old ages. Depending on those assumptions, I indicated that the estimates could be overstated by 20 percent.

The assumptions for the discount rate and utility function parameters (γ homogeneity assumptions) are major factors influencing the results of the estimate. The interest rate is the average real, long-term interest rate of 3 percent, while γ is set at 1/3. However, I observed in Figures 3.2 and 3.3 how WTP changes when $0.01 \leq r \leq 0.25$, and $0.1 \leq \gamma \leq 1$. For these reasons, the above results should be interpreted with considerable latitude.

I also analyzed the effect of two demographic changes from 1970, the increase in population and its compositional changes, on the results of my estimate. These two factors contributed to an increase in WTP of 30 trillion yen and 20 trillion yen, respectively. Furthermore, based on changes in survival rates projected from 2005 to 2040, given 2005 population figures, WTP is expected to be about 2,300 trillion yen or about 40 percent of WTP for 1970-2005. If we determine WTP based on the population as of 2040, we get 2,048 trillion yen because of the decrease in the population. Although the pace of the decrease in population has somewhat leveled off, baby boomers are now reaching the older age at which per capita WTP becomes higher, so the WTP should continue to rise. One of the current difficulties in containing health-care costs growth is that this drive to actually expand health-care expenditures is becoming more apparent.

In a cost-benefit analysis, with cost as the discounted present value of the increases in health-care expenditures, the cost from 1970 to 2005 is 538 trillion yen, or about one-tenth of the WTP. Although this cost-benefit analysis is very rough, the increase in health-care costs up to now may be reasonable and understandable.

Our estimate of the WTP seems consistent with newly available estimates by UNU-IHDP and UNEP (2012). Their *Inclusive Wealth Report* provided estimates of health capital of Japan for the period 1990 to 2008, based on Arrow *et al*. (2012). Their estimate of change in health capital from 1990 to 2005 is 23 trillion dollars, which is a quarter larger than our estimate, 1,829 trillion yen, assuming 1 dollar is equal to 100 yen. The difference could reflect the fact that the report is based on the concept of health, not just longevity. In a cost-benefit analysis, however, health care can be considered from the aspect of not only investment but also consumption, and not only health expenditures but also other numerous factors (e.g. improvements in public sanitation and diets) can be regarded as costs for extension of life span. Based on such perspectives, we need to improve cost-benefit analyses in the future with this study as a beginning.

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Appendix Details of Data Used

This appendix will explain how to calculate the variables in Section 3.1.

- I selected 3 percent for the discount interest rate, r, used in the data, considering the average real, long-term interest rate after the 1990s. However, to obtain the expected rate of inflation in order to calculate the real interest rate, I used the actual consumer price index (excluding perishable food) from the previous year.
- The survival rate is determined from stationary population, S, according to the sex and age bracket from the life table published by the Ministry of Health, Labor, and Welfare. S^1 comes from the Twentieth Life Table (2005), while S^2 comes from the Thirteenth Life Table (1970).
- Goods and services, x_t, is the sum of expenditures (excluding health care costs) by sex, broken down in 10-year age brackets, and imputed rent, both of which are taken from the National Survey of Family Income and Expenditure (2004) published by the Ministry of Internal Affairs and Communications. I expressed these expenditures in the 2005 prices, using the consumer price index. Since it is difficult to determine the expenditure pattern over the life cycle in households with multiple members, I used data for single-person households. Furthermore, I add imputed rent to eliminate the differences that arise from living circumstances where homes are either owned or rented.
- Data for wages, w_t, come from hourly wages divided according to company size (more than 10 people and five to nine people) for general and part-time workers in each age bracket, by sex, compiled by the Ministry of Health, Labor, and Welfare’s Survey of Wage Structure (2004). I then calculated their weighted average for the number of workers. The data for wages was divided into two groups: (1) regular wages and (2) nonregular wages, that is, wages including overtime payments and bonuses. I then converted these numbers in terms of 2005 price levels using the consumer price index.
- Leisure time, l_t, is derived from total average time for tertiary activities, by age bracket and by sex, compiled by the Ministry of Internal Affairs and Communications, Survey on Time Use and Leisure Activities (2006).

Tertiary activities include time devoted to transportation other than to work or school; watching television, listening to the radio, reading the newspaper, and other such relaxation; study time other than at school; and time devoted to hobbies or entertainment and sports; and volunteer activities and other social activities, meetings, health care, and so on.

- Population, N_t, is the population according to one-year age brackets for each sex compiled by the Ministry of Internal Affairs and Communications in the National Census (2005). However, the only statistic available for persons older than 100 is the total population older than 100, by sex.