INSTITUT DES ACTUAIRES

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Deferred Public Pension and Longevity Risk for a Household in Retirement

Norio Hibiki (Keio University)

Masahiro Shibahara (Mizuho-DL Financial Technology Co., Ltd.)

Paris, May 14th, 2020

About the speaker

SECTIONS VIRTUAL COLLOQUIUM 2020

Norio Hibiki

- Professor
- Major research field: Financial Engineering (asset allocation, risk management, household finance, pension)
- Awarded for the best scientific paper at the PBSS Colloquium, St. John's 2016

Department of Industrial and Systems Engineering, Keio University (Japan)

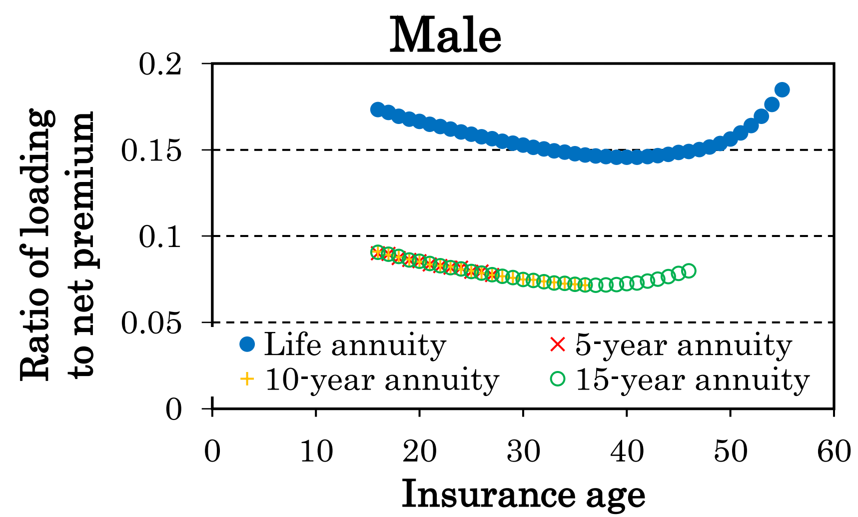
- Department was founded in 1959.
- Research fields of my department are applied statistics, operations research, financial engineering, economics, computer science, system and human engineering, production management, and so on.

Contents

Keywords : public pension, deferral option, longevity risk, optimization model

1. Introduction (1)

- ✓ Recently, managing longevity risk of outliving one's wealth is a very important issue for a household in retirement.
- ✓ Many literatures show that it is effective to purchase private life annuity in addition to public pension annuity in order to avoid longevity risk.(Horneff et al.(2010), Hibiki and Oya(2015) etc.)
- ✓ However, the private life annuity has a problem that it is more expensive than the term annuity.



◆ Instead of the private life annuity, we examine the deferral options of public pension as a tool of hedging longevity risk.

1. Introduction (2) : Deferral options of public pension

- We can receive an increased amount of pension by delaying the start of receiving from the normal age (65 years old).
  - Increment rate = (Number of months from normal age to starting age) × $\boxed{0.7\%}$
    Monthly deferred premium

Starting age	Increment rate
Age 66	8.4%
Age 68	25.2%
Age 70	42.0%

  - Current ratio of deferred public pension benefit = 1 to 2 %
  - The increase in the pension benefit is expected to contribute to the reduction of longevity risk.
- If the deferred recipients of pension benefit increase, it gives the large impact on the public pension finance.

◆ We investigate how to determine the increment rate for deferred pension in consideration of both the sustainability of public pension system and longevity risk of household.

1. Introduction (3)

Summary of public pension systems for major countries

Country		Japan	U.S.A.	U.K.	Germany	France
pensionable age (*)		age 65	age 67	age 68	age 67	age 62
advance option from		age 60	age 62	impossible	age 63	impossible
(reduction rate/year)		6.0%	6.7% for 3 years 5% later		3.60%	
deferral option until		age 70	age 70	no limit	no limit	no limit
(increment rate/year)		8.40%	8.00%	5.80%	6.00%	5.00%
average life expectancy	male	81.1 years	76.0 years	79.7 years	78.7 years	80.1 years
	female	87.1 years	81.0 years	83.2 years	83.3 years	85.7 years

(*) As of September 24, 2018

◆ The table is generated according to social security and national government websites, World Health Organization(2018).

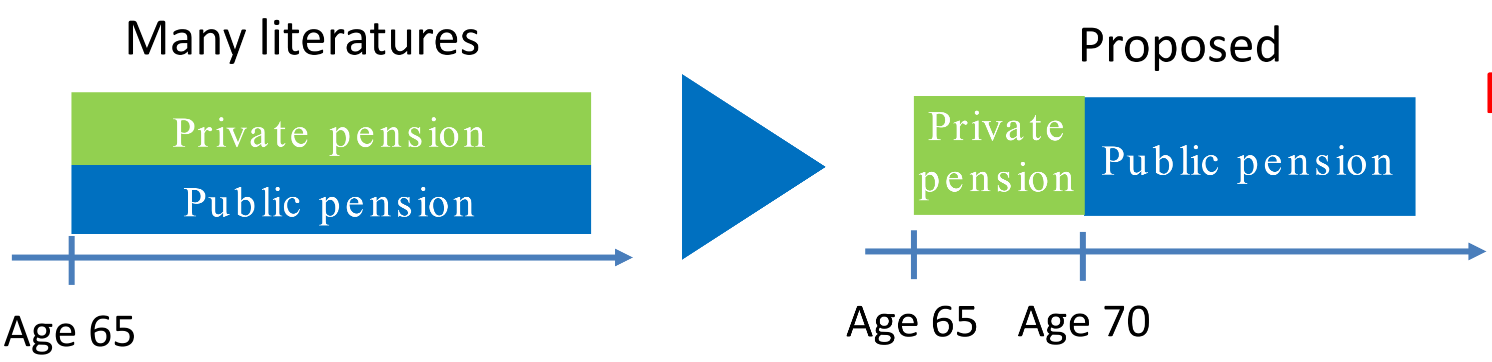
1. Introduction (4)
Previous studies w.r.t. deferral options of public pension

Authors	Country	
Farrar et al. (2012)	UK	・Examine the value of incentives to defer the UK state pension by comparing the values of pension receipt at the end of the deferral period for three kinds of choice
Rose(2015)	U.S.	・Examine the rate of return on delaying social security retirement benefits for individuals and for married couples in the U.S. when the start of the benefits is postponed.
Genest-Gregoire et al.(2018)	Canada	・Compare the differences among the cases for various starting age of pension benefits through the simulations ・Show that the efficient use of public pension benefit deferrals can reduce the cost of the precautionary behavior.
Moizer et al.(2018)	UK	・Construct the state pension deferral system dynamics model, and examine the impact of pension deferral upon the sustainability of the UK's state pension system.
Kenjoh et al.(2017)	Japan	・Describe that the private term annuity is purchased until the pensionable age of deferred public pension to hedge the longevity risk, instead of purchasing private life annuity in addition to public pension annuity

1. Introduction (5) : Previous studies in Japan

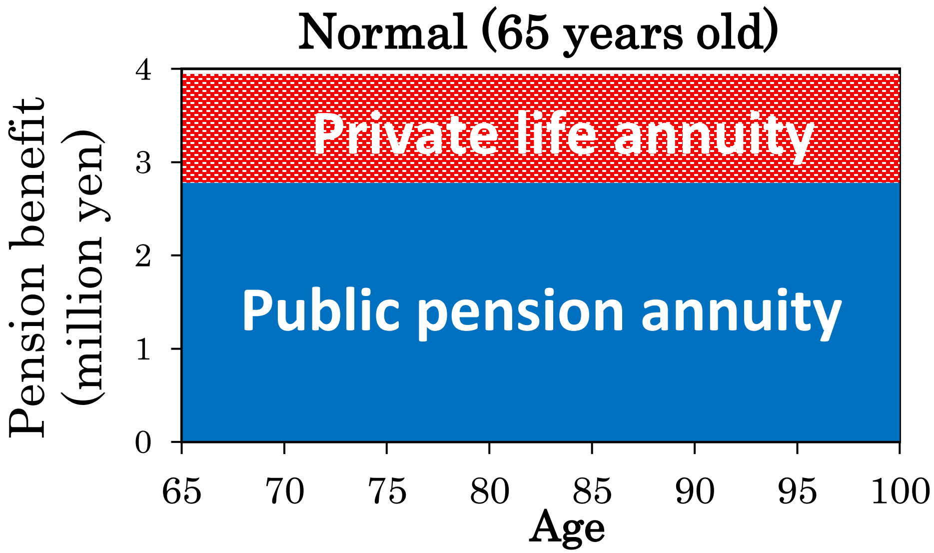
- Kenjoh et al.(2017) describe that the longevity risk should be managed by using the deferred public pension benefit.
- Why is the public pension superior to the private pension for managing longevity risk?
  1. Public pension has lower administrative costs than private pension.
  2. Adverse selection is unlikely to occur and insurance premiums are cheaper because the public pension is mandatory.

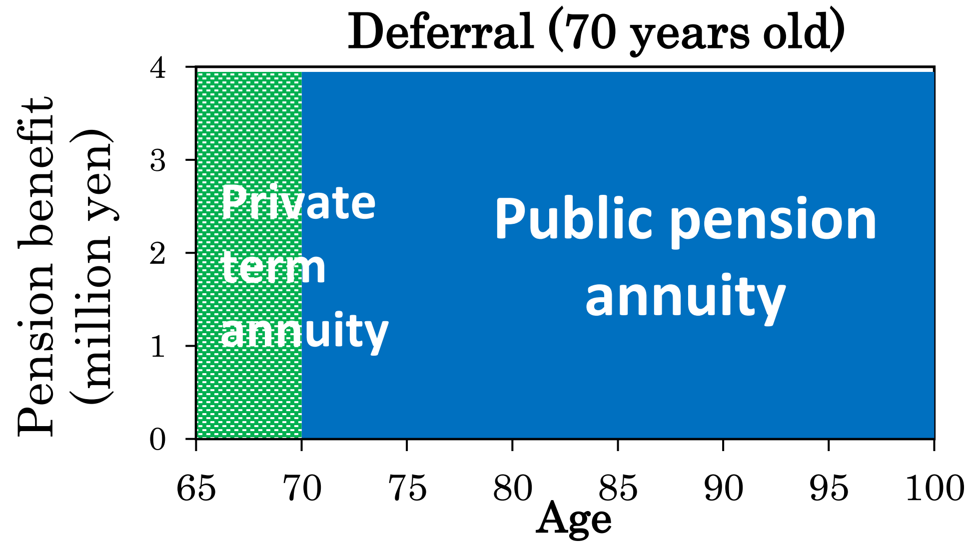
Kenjoh et al.(2017) : Concept of combination of pensions for managing longevity risk



No quantitative evaluation

1. Introduction (6) : Examining the deferral effect





- The private life annuity is purchased in addition to public pension annuity for all retirement periods
- Private pension premium = 29.9 million yen

- The private term annuity is purchased until the pensionable age of deferred public pension
- Private pension premium = 19.7 million yen

◆ The result shows the use of deferral option is effective due to the reduction of the premium for the same cash flow stream

1. Introduction (7) : Retirement Planning and Public Pension

Retired Household	Public Pension System
Goal: Longevity Risk Management	Goal: Retirement Security & Sustainability
Optimization Model ➢ Evaluate longevity risk for normal and deferred receipts	Simulation Model ➢ Construct model of public pension finance based on Yokoyama(2013)
Question ➢ Is deferred receipt is useful and effective for households? ➢ What is the lower bound of increment rate for deferred pension?	Question ➢ How is the impact on the increase in deferred recipients? ➢ What is the upper bound of increment rate for deferred pension?

Increment rate for deferred pension

Which rate can manage longevity risk more than normal receipt? ⟺ Which rate can maintain current public pension finance?

◆ We need to build the win-win relationship between the retired household and public pension system in consideration of both the longevity risk of households and the sustainability of public pension finance.

1. Introduction (8) Purpose and Contribution

- ✓ We evaluate the longevity risk quantitatively involving the household to examine the effect of deferral option of public pension.
- ✓ Specifically, we examine the usefulness of the combination of deferred public annuity and term private annuity by comparing it with the combination of normal public pension and life private annuity in order to reduce longevity risk in retirement quantitatively using the optimization model.
- ✓ We examine how the increment rate for deferred pension affects both the sustainability of public pension system and longevity risk of household, and we attempt to build a win-win relationship between them.

2. Modeling for retirement planning : Model structure

Interest rate

Nelson-Siegel Model

+

Rate of return of risky assets

Normal distribution

Mortality rate

Lee-Carter method

Household

- 65-year-old retired householder and spouse
- 35-year problem from 65 to 100 years old

Income

- Public pension
- Private pension
- Life insurance money

Investment

- Risk-free asset
- Risky assets

Expenditure

- Minimum living cost
- Medical expense (log-normal dist.)
- Life insurance premium
- Private pension premium (time 0)

Optimization model

Decision Variables (time 0)

- Private pension (term or life)
- 15-year life insurance

Parameters

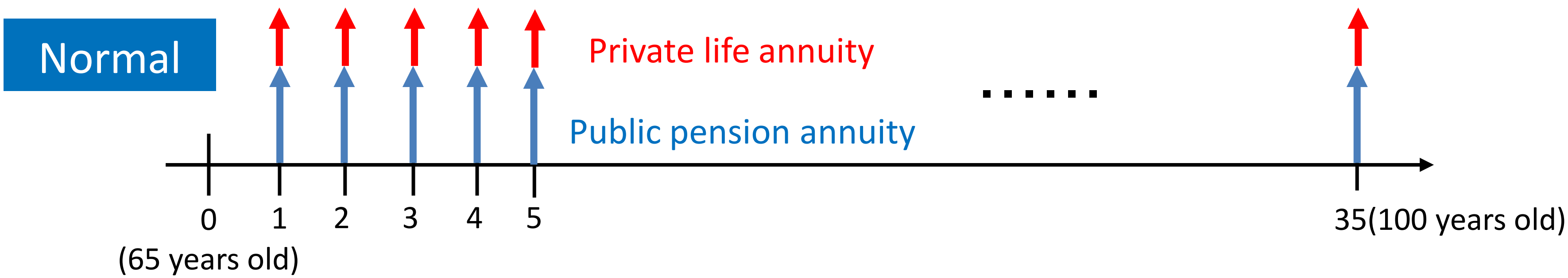
Weights of risky asset

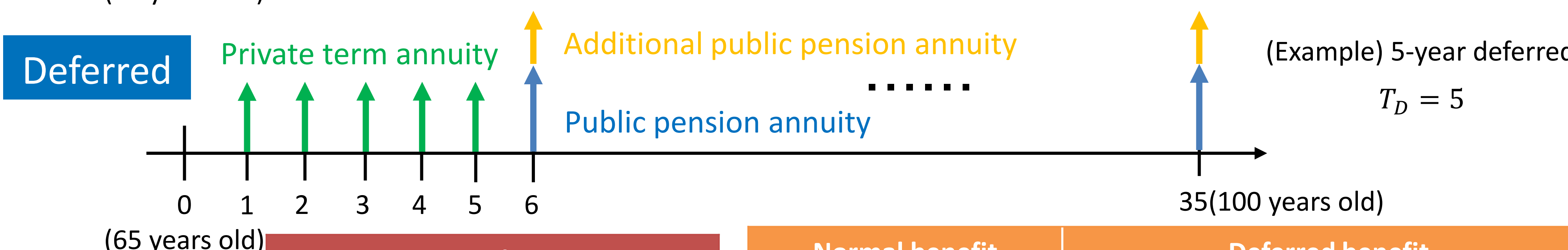
Estimating parameters for market data, etc. → Estimating parameters for household → Optimization

2. Modeling for retirement planning (2) : Household's cash flow

Setting

- Householder is now retired at age 65 for the 100-year life, and we formulate the model for a 35-year problem. Cash flow occurs at the end of each year.
- Cash flow continues for 35 years or until household is diminished.
- Cash flow at each time is affected by status of household.





Decision variables at time 0
Purchase units of private pension and life insurance

Expenditure	
Time 1 to 14	Time 15 to 35
Minimum living and medical costs	
Life insurance premium	—

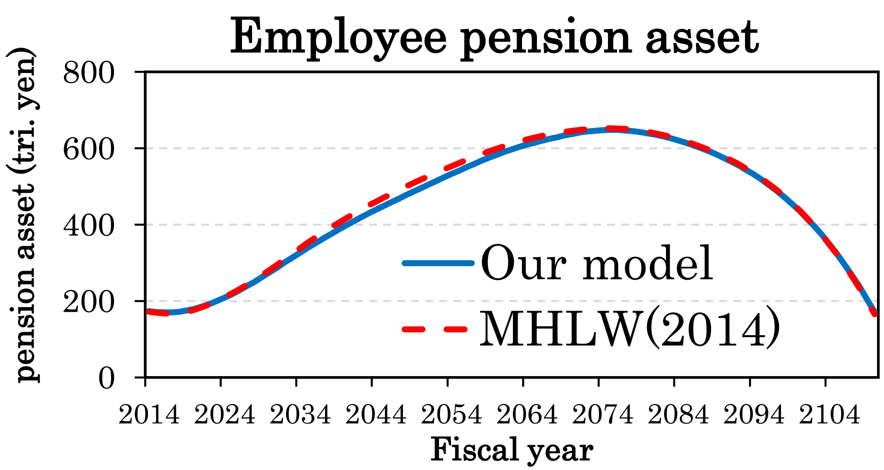
Normal benefit	Deferred benefit	
Income: Time 1 to 35	Time 1 to T_D	Time $(T_D + 1)$ to 35
Public and Private annuities	Private term annuity	Public pension annuity

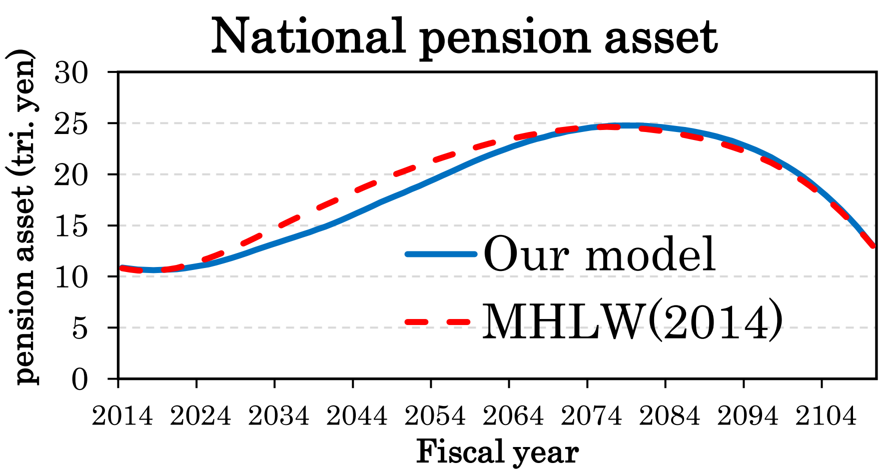
Time 1 to 15	Time 16 to 35
Life insurance money	—

3. Modeling public pension finance (1) : Yokoyama (2013)

- Ministry of Health, Labour and Welfare(MHLW) examines public pension finance every five years
  - The program code is published by MHLW, but it is hard to use due to its size and complexity.
  - The research is being conducted in order to reproduce the estimation results of MHLW.
- Yokoyama(2013) developed an actuarial model that can reproduce the estimation results of the MHLW(2009) as faithfully as possible using published data
- We construct the model of public pension finance with reference to Yokoyama(2013) in order to examine the effect of receiving the deferred pension.

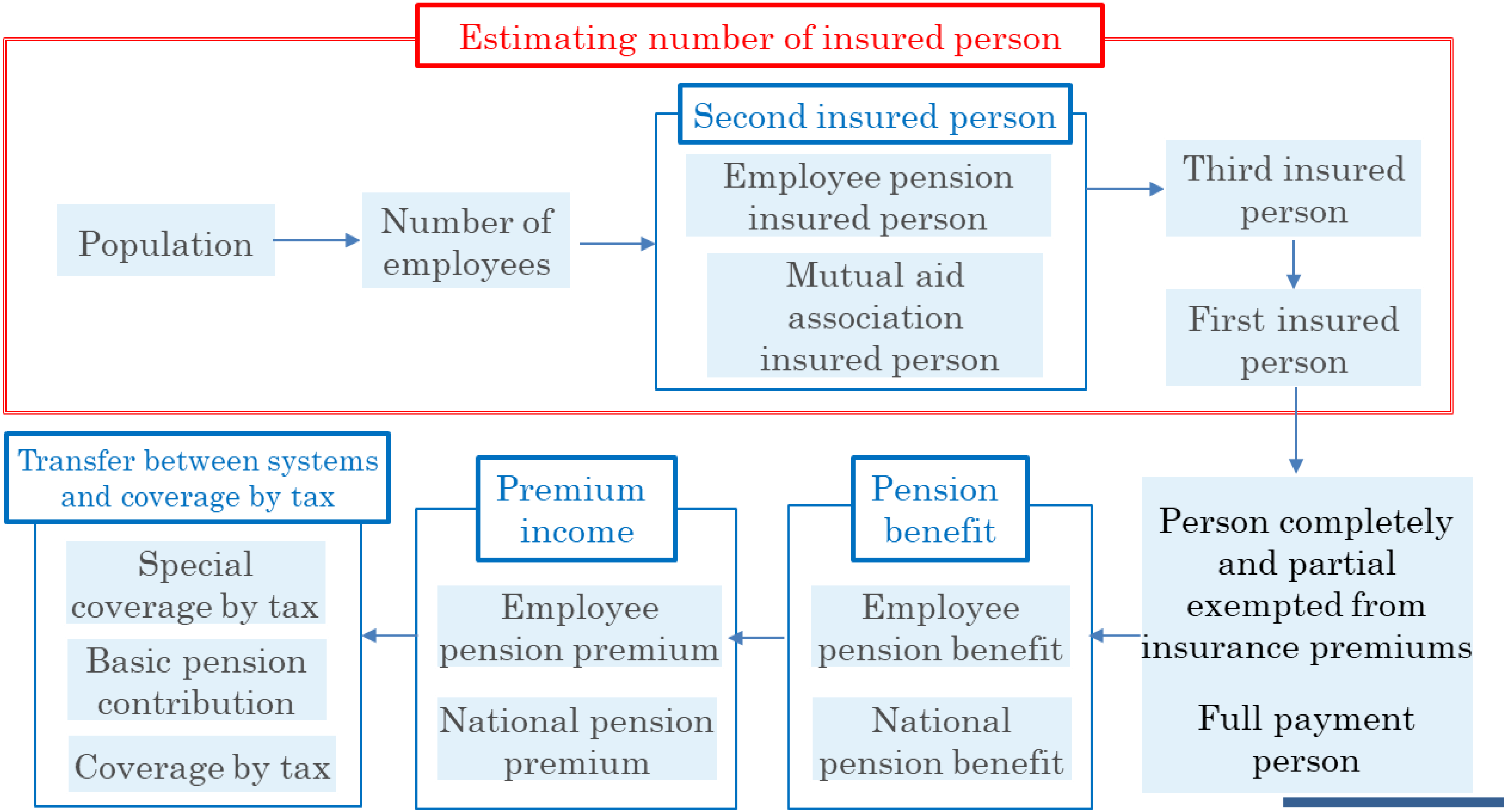
Comparison of estimation results with MHLW(2014)





- We find our model has the similar results to MHLW(2014).

3. Modeling public pension finance (2) : Overview



- We construct the model with reference to Yokoyama(2013).

4. Optimization model for retired household(1) : Formulation

Optimization model in simulation-based approach

- Objective function : Minimizing longevity risk defined as the amount of wealth below zero target (negative wealth) at each time
- Risk measure: First-order lower partial moment (LPM(1)) with zero target

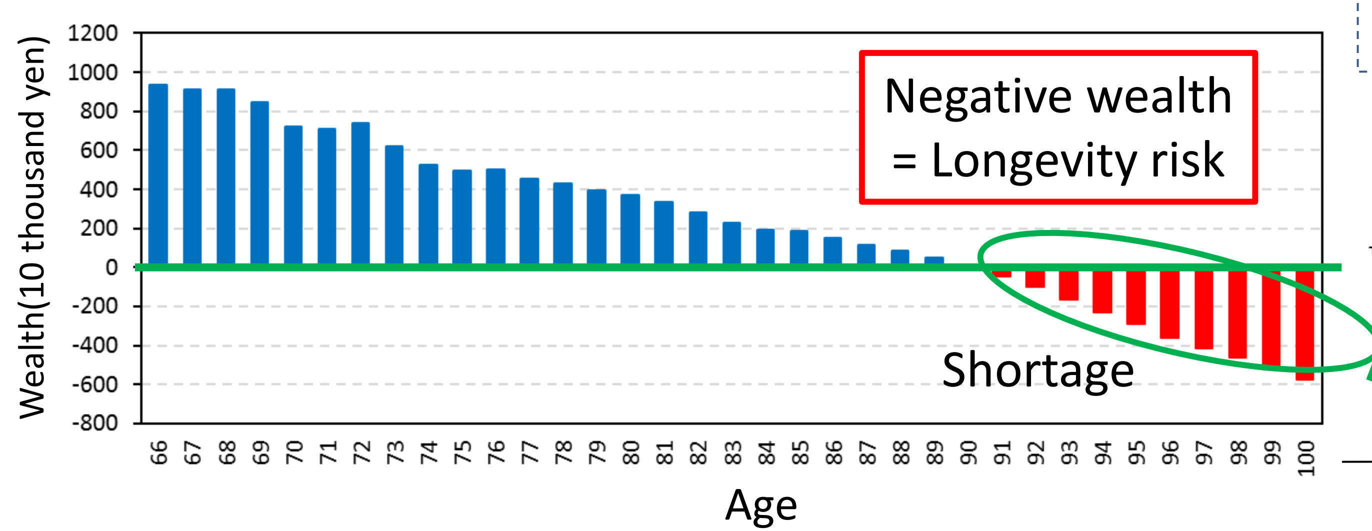
Objective function

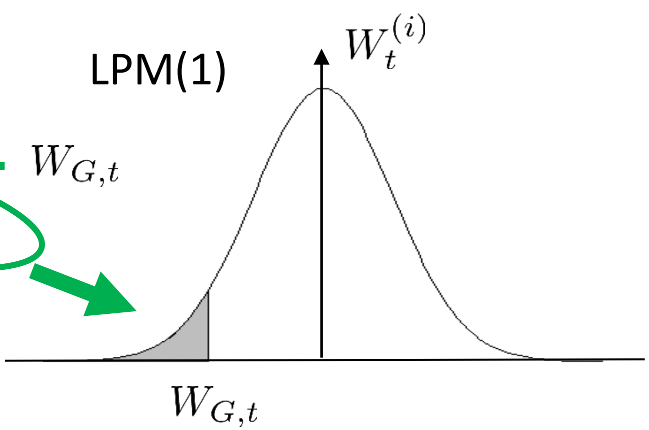
$$\text{Min} \quad \frac{1}{I}\sum_{i=1}^{I}\sum_{t=1}^{T}\tau_{A,t}^{(i)} df_t q_t^{(i)}$$

Const. for LPM(1)

$$\underbrace{W_t^{(i)}}_{\text{Wealth}} + \underbrace{q_t^{(i)}}_{\text{Shortfall}} \geq \underbrace{W_{G,t}}_{\text{Target = 0}};\ q_t^{(i)} \geq 0$$

I : number of paths
T : number of periods
$\tau_{A,t}^{(i)}$: one if any member is alive, and zero otherwise
df_t : discount factor





We evaluate longevity risk quantitatively using LPM(1).

4. Optimization model (2): Formulation

Minimize $\frac{1}{I}\sum_{i=1}^{I}\sum_{t=1}^{T}\tau_{A,t}^{(i)} df_t q_t^{(i)}$ Average LPM(1)

subject to

$$W_t^{(i)} = \begin{cases} \left(1+\mu_{P1}^{(i)}\right)(W_0 - D_0^-) + D_1^{(i)} & (t=1) \\ \left(1+\mu_{Pt}^{(i)}\eta_{W,t-1}^{(i)}\right) W_{t-1}^{(i)} + D_t^{(i)} & (t=2,\ldots,T) \end{cases}$$

$$\eta_{Wt}^{(i)} = \begin{cases} 1 & \text{for } W_t^{(i)} > 0 \\ 0 & \text{otherwise} \end{cases} \quad (t=1,\ldots,T-1)$$

$W_t^{(i)} + q_t^{(i)} \geq W_{G,t};\ q_t^{(i)} \geq 0$ Const. for LPM(1)

$x_M \geq 0;\ x_F \geq 0$

$y_M \geq 0;\ y_F \geq 0$ Non-negative constrains

$A_0^- = A_M x_M + A_F x_F$ Private pension: (-)out, (+) in

$A_t^{+(i)} = a_M x_M \tau_{AM,t}^{(i)} + a_F x_F \tau_{AF,t}^{(i)} \quad (t=1,\ldots,T_A)$

$L_0^- = L_M y_M + L_F y_F$ Life insurance: (-)out, (+) in

$L_t^{-(i)} = L_M y_M \tau_{AM,t}^{(i)} + L_F y_F \tau_{AF,t}^{(i)} \quad (t=1,\ldots,T_L-1)$

$L_t^{+(i)} = \theta_M y_M \tau_{LM,t}^{(i)} + \theta_F y_F \tau_{LF,t}^{(i)} \quad (t=1,\ldots,T_L)$

$D_0^- = A_0^- + L_0^-$

$D_t^{-(i)} = L_t^{-(i)} + C_{d,t}^{(i)} + H_t^{(i)}$ Cash outflow (-)

$D_t^{+(i)} = A_t^{+(i)} + L_t^{+(i)} + P_t^{(i)}$ Cash inflow (+)

$D_t^{(i)} = D_t^{+(i)} - D_t^{-(i)}$ Net cashflow

(1) Parameters

$\mu_{Pt}^{(i)}$: rate of return of portfolio
df_t : discount factor used for cashflow
W_0 : initial amount of wealth
$P_t^{(i)}$: disposable income
$C_{d,t}^{(i)}$: minimum living expense
$H_t^{(i)}$: medical expense
$A_M,\ A_F$: private pension premiums per unit at time 0
$a_M,\ a_F$: private pension incomes per unit at time 0
$L_M,\ L_F$: premiums of level payment life insurance per unit bought at time 0
$\theta_M,\ \theta_F$: life insurance money per unit bought at time 0
$T_A,\ T_L$: maturity of private pension and life insurance
κ : relative consumption level after a householder or a spouse died
$W_{G,t}$: target wealth at time t

(2) Decision variables

$x_M,\ x_F$: numbers of units of private pension at time 0
$y_M,\ y_F$: numbers of units of life insurance at time 0
$W_t^{(i)}$: wealth
$q_t^{(i)}$: shortfall from target wealth
$\eta_{Wt}^{(i)}$: one for $W_t^{(i)} > 0$ and zero otherwise

5. Numerical Analysis (1-1): Household Setting

Base parameters

Parameter		Value
Initial wealth (million yen)		15.52
old-age basic pension (million yen)	householder	0.78
	spouse	0.78
old-age employee pension (million yen)	householder	1.22
	spouse	0
Minimum living cost (million yen)		2.82
Medical expense		Age Dependent
Number of paths		10,000
Inflation rate		0.65%
amounts of private pension benefit per unit(million yen)		0.9
amounts of life insurance money per unit(million yen)		10

Mathematical programming software

➢ Numerical Optimizer Ver 20.1.0 (NTT DATA Mathematical System, Inc.)

Private pension premiums per unit (million yen)

Maturity	life	1 yr	2 yr	3 yr	4 yr	5 yr
Male	21.195	0.9	1.8	2.7	3.6	4.5
Female	27.785	0.9	1.8	2.7	3.6	4.5

- Virtual private pensions are generated, based on "& LIFE individual annuity insurance", life annuity with 10-year guaranteed period (Mitsui Sumitomo Aioi Life Insurance Company, Limited, and 0.75% guaranteed rate.

Life insurance premiums(million yen)

	Term	Premium
Male	15 yr	0.2367
Female	15 yr	0.1165

- "Bridge", 15-year term insurance (OLIX life insurance corporation)

5. Numerical Analysis (1-2): Investment Setting

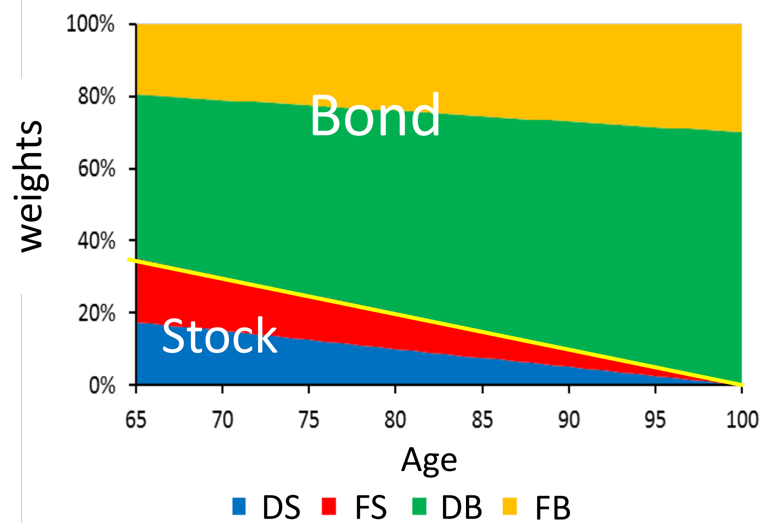
Investment assets

- Domestic stock (DS) : TOPIX
- Domestic bond (DB) : FTSE Japan GBI LCL
- Foreign stock (FS) : MSCI International index
- Foreign bond (FB) : FTSE Non-JPY World Government Bond Index in JPY term
- Risk-free asset : Spot rate of one-year Japanese GBI
- Data period: historical annual rate of return from 1993 to 2015

	DS	DB	FS	FB
Expected return	3.13%	2.73%	7.52%	6.79%
Standard deviation	24.43%	3.08%	18.53%	12.41%

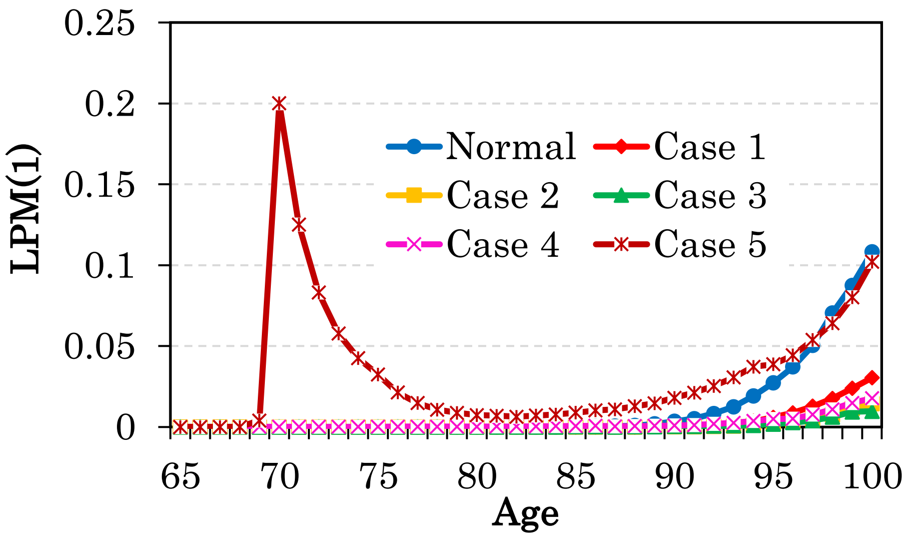
Investment weights

- Investment rule of the “100 minus age” % for stock, “age” % for bond, which is a well-known simple method for risky assets in the U.S.
- We set the fraction between domestic and foreign assets in reference to asset mix of the Government Pension Investment Fund in Japan
  - Stock: DS : FS＝1 : 1
  - Bond: DB : FB＝7 : 3

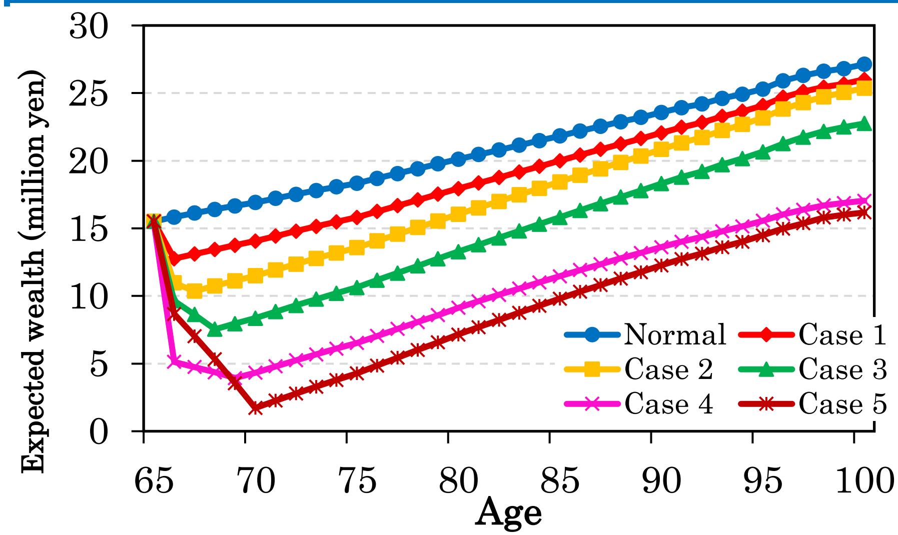


5. Numerical Analysis (2): Basic Analysis

LPM(1) for each pensionable age



Expected wealth for each pensionable age



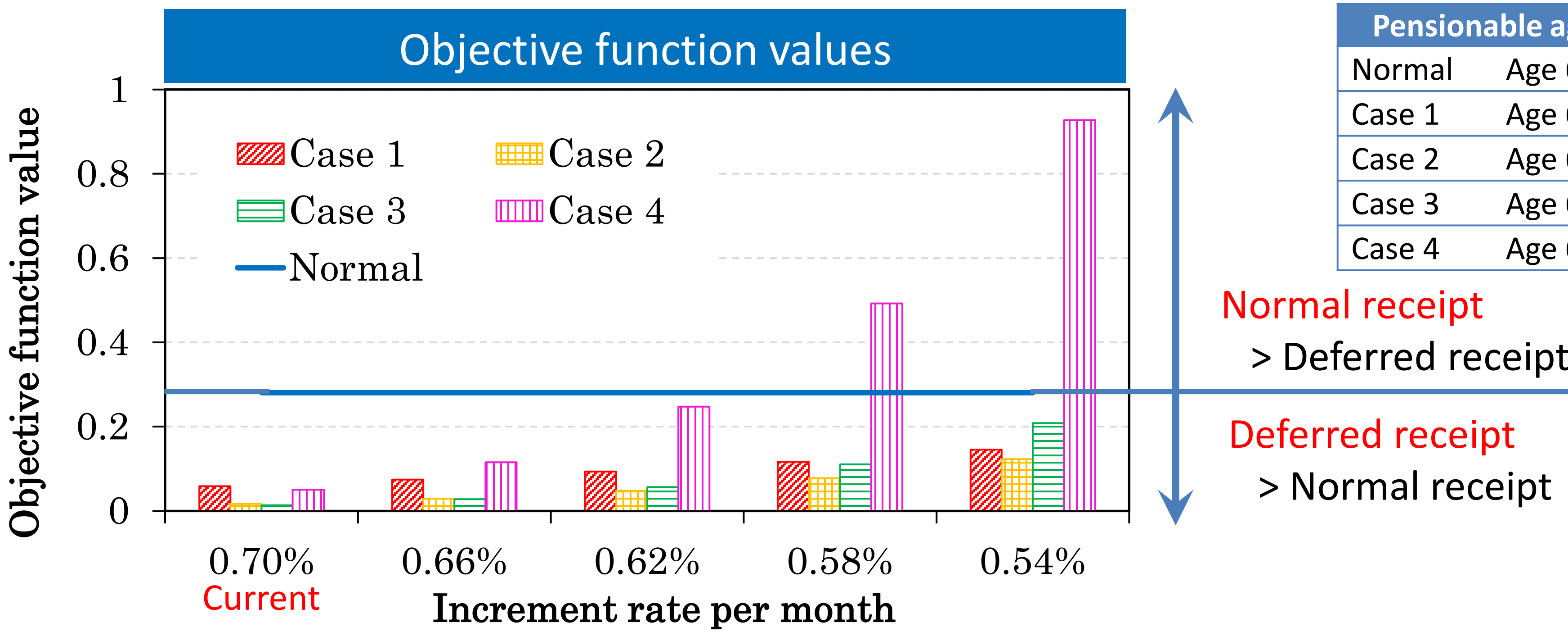
	Pensionable age	Maturity of Private annuity	Objective function value
Normal	Age 65	life	0.2807
Case 1	Age 66	1 year	0.0587
Case 2	Age 67	2 year	0.0169
Case 3	Age 68	3 year	**0.0131**
Case 4	Age 69	4 year	0.0505
Case 5	Age 70	5 year	2.1702

- ✓ Normal Case: Household is exposed to longevity risk at the end period because the public pension benefits are not enough to live for the whole period
- ✓ Case 5: Savings are likely to be exhausted before the receipts
- ✓ Case 1 to 4 : Longevity risk can be hedged more appropriately due to sufficient income after the start of receipt

We find the deferred receipt of public pension is effective for hedging longevity risk.

5. Numerical Analysis (3): Sensitivity analysis of increment rate for deferred pension

We examine the impact on retired household for the different increment rates



Pensionable age	
Normal	Age 65
Case 1	Age 66
Case 2	Age 67
Case 3	Age 68
Case 4	Age 69

- Even if it is reduced from the current level of 0.7% to 0.54%, we find that the deferred receipt is still useful in Cases 1 to 3.
- Increment rate is highly sensitive to the objective function values of Case 4.
- Reducing increment rate helps public pension finance, but impacts on the longevity risk for retired households. However, we can manage the longevity risk by receiving deferred benefits, even if the increment rate is reduced.

5. Numerical Analysis (4-1): Effect of asset mix

- We find the effectiveness of deferral receipts under the well-known simple investment rule of the “100 minus age” percentage for stock.
- Current situation of elderly people in Japan for investing risky asset

Source: Statistic Bureau, the Ministry of Internal Affairs and Communications (2017)

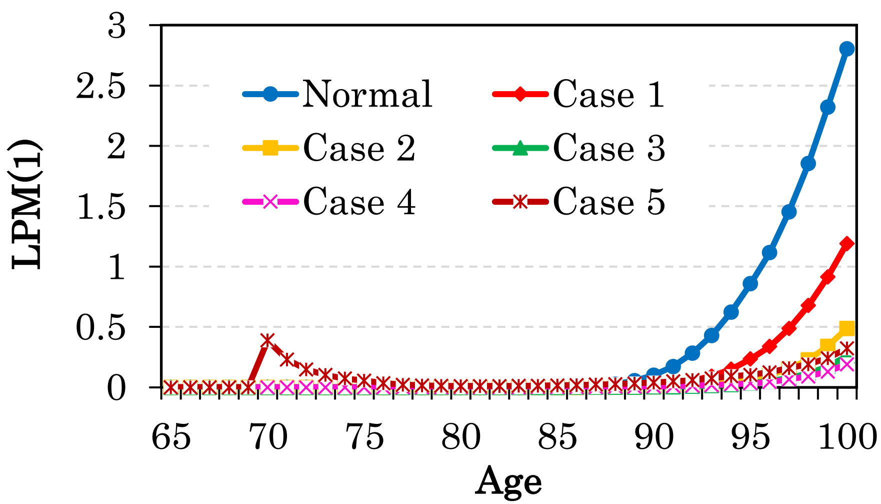
- ✓ We solve the problem with constant asset mix, based on the current situation;
  - ✓ Risk-free asset: 92.94%
  - ✓ Stock： 5.54%(DS：FS=1:1)
  - ✓ Bond: 1.52%(DB：FB=7:3)

	Pensionable age	Maturity of Private annuity	Objective function value	
			Current	100 - age
Normal	Age 65	life	7.3098	0.2807
Case 1	Age 66	1 year	2.2920	0.0587
Case 2	Age 67	2 year	0.7517	0.0169
Case 3	Age 68	3 year	**0.3938**	**0.0131**
Case 4	Age 69	4 year	0.3993	0.0505
Case 5	Age 70	5 year	4.2679	2.1702

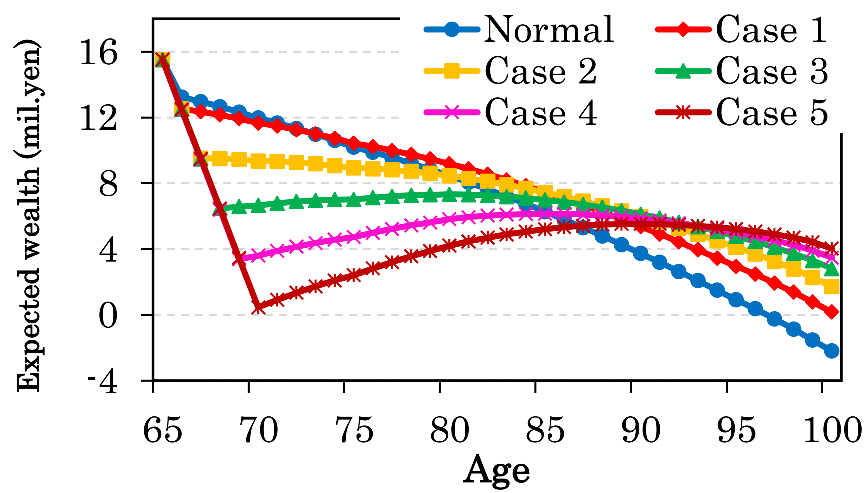
- ✓ The objective function values are larger than those of “100 minus age” strategy in all cases, and we find investing in risky assets helps the reduction of longevity risks for elderly households even a simple investment rule.

1. Numerical Analysis (4-2): Effect of asset mix

LPM(1) for each pensionable age



Expected wealth for each pensionable age



- ✓ The household is exposed to a large longevity risk at the end of planning period in the normal case and Case 1, receiving public pension benefit from age 65 and 66 because of investment in the risk-free asset.
- ✓ Longevity risk can be managed appropriately at the end of planning period by receiving deferred pension benefits

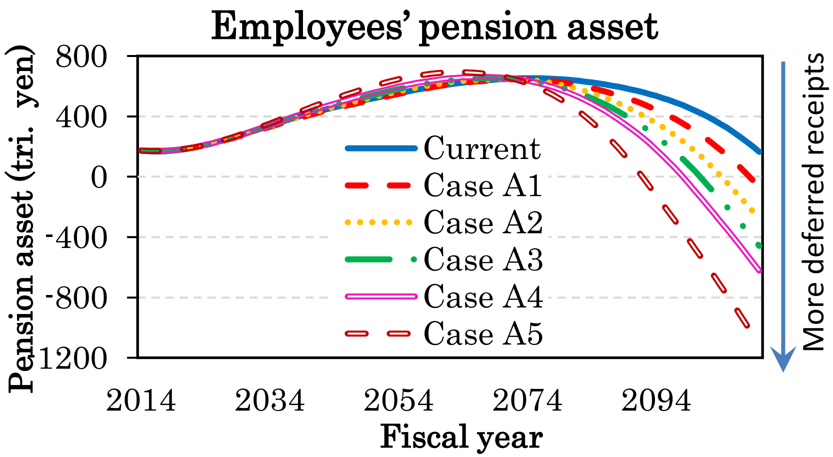
Pensionable age	
Normal	Age 65
Case 1	Age 66
Case 2	Age 67
Case 3	Age 68
Case 4	Age 69
Case 5	Age 70

- Considering the investment environment in Japan, the annual increment rate of 8.4 % due to deferred payments is very attractive for many elderly people even with insufficient financial literacy.

5. Numerical Analysis (5-1): Impact on public pension finance

We examine the impact when the ratio of deferred recipients of public pension increases.

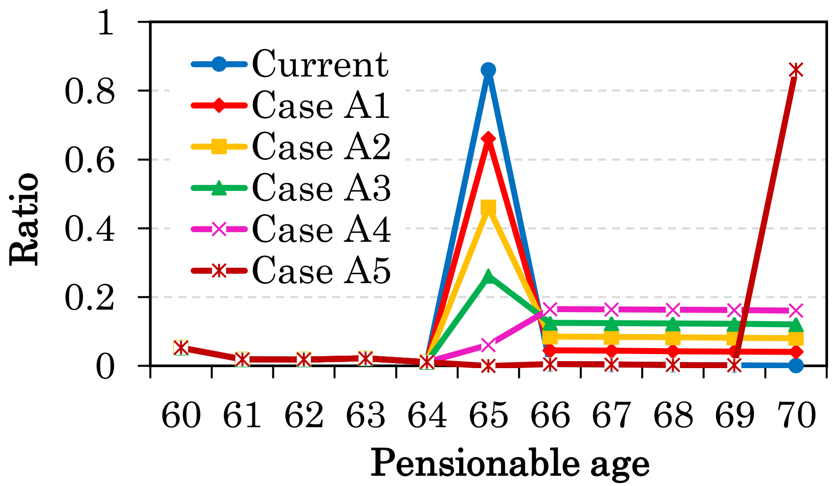
Employees' pension finance: asset and balance sheet



Unit: trillion yen	Current	Case A1	Case A2	Case A3	Case A4	Case A5
Premium	1,332.8	1,332.8	1,332.8	1,332.8	1,332.8	1,332.8
Tax revenue	368.1	369.0	369.9	370.9	371.8	374.8
Pension asset	173.8	173.8	173.8	173.8	173.8	173.8
Total asset	1,874.6	1,875.6	1,876.5	1,877.4	1,878.4	1,881.4
Pension benefit	1,141.5	1,145.0	1,148.5	1,151.9	1,155.4	1,167.7
Contribution	726.3	728.2	730.1	732.0	733.8	739.9
Total liability	1,867.9	1,873.2	1,878.6	1,883.9	1,889.2	1,907.6
Net debt	-6.8	-2.3	2.1	6.5	10.9	26.2

More deferred receipts are promoted

Ratio of starting benefit reception

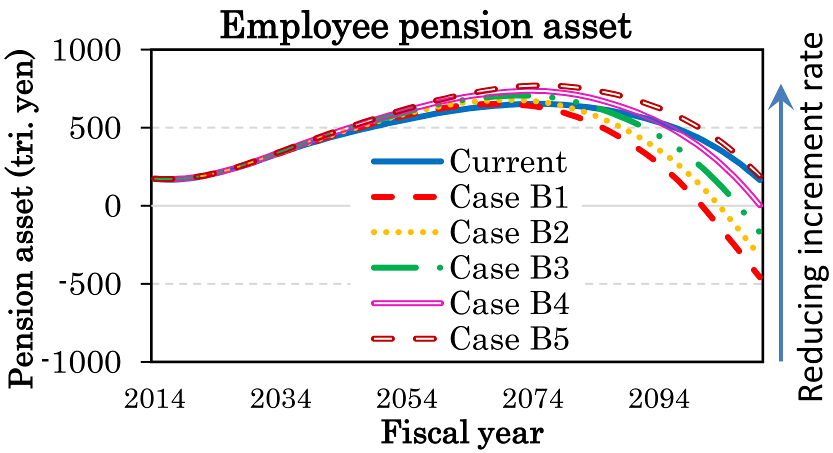


- ✓ More deferred receipts worsen employees' pension finance.
- ✓ Increment rate should be reduced to maintain pension finance.

5. Numerical Analysis (5-2): Impact on public pension finance

We examine the impact by reducing increment rates for deferred pension.

Employees' pension finance: asset and balance sheet



Unit: trillion yen	Current	Case B1	Case B2	Case A3	Case A4	Case A5
Premium	1,332.8	1,332.8	1,332.8	1,332.8	1,332.8	1,332.8
Tax revenue	368.1	370.9	370.3	369.8	369.2	368.7
Pension asset	173.8	173.8	173.8	173.8	173.8	173.8
Total asset	1,874.6	1,877.4	1,876.9	1,876.3	1,875.8	1,875.2
Pension benefit	1,141.5	1,151.9	1,149.0	1,146.0	1,143.1	1,140.1
Contribution	726.3	732.0	730.9	729.8	728.7	727.6
Total liability	1,867.9	1,883.9	1,879.9	1,875.8	1,871.8	1,867.7
Net debt	-6.8	6.5	3.0	-0.5	-4.0	-7.5

Reducing increment rates

Reducing increment rate

	Deferral ratio	Increment rate/month
Case B1	Case A3	0.70%(*1)
Case B2		0.68%
Case B3		0.66%
Case B4		0.64%
Case B5		0.62%

(*1) current rate

- ✓ We find that pension finance can be maintained even if the number of deferred beneficiaries increases by decreasing the increment rate for deferred pension.
- ✓ Therefore, it is necessary to properly discuss how to reduce the increment rate for deferred pension in order to build a win-win relationship between public pension finance and household.

6. Conclusion

- ✓ We show quantitatively that it is effective to use a public pension deferral option after receiving a private term annuity, instead of receiving a private life annuity together with a public pension.
- ✓ We find the deferral option is effective for managing longevity risk.
- ✓ The public pension finance becomes worse if the number of deferred recipients increases at the current increment rate.
- ✓ It is expected the win-win relationship is built between the retired household and public pension finance by setting appropriate increment rate.
- ✓ Future research
  - ✓ It is necessary to conduct the analysis in a more realistic framework in order to design the public pension system.
  - ✓ We also need to formulate the optimization model of obtaining the optimal asset allocation.

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Thank you for your attention

Contact details :

NORIO HIBIKI

Department of Industrial and Systems Engineering
Faculty of Science and Technology, Keio University

3-14-1 Hiyoshi, Kohoku-ku
Yokohama, 223-8522
Japan

hibiki@ae.keio.ac.jp

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