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New Evidence in Korea: Annuity Puzzle and Properties

Dong-Hwa Lee[a], Jun-Hee An[b] and Joo-Ho Sung[c]

Abstract

Many assume that for retirees, purchasing an annuity is a better option than self-annuitization in the post-retirement period. Using genetic algorithm, we show that self-annuitization can be an optimal choice for retirees in Korea if we consider properties (real estate) as one of the investment options. We set three scenarios that a worker can choose at the retirement: self-annuitization, purchasing a whole-life annuity, and mixed strategy. Then we calculate optimal asset allocation for each scenario that minimizes probability of ruin (PoR). We find that the PoR increases significantly as the preference for purchasing a whole-life annuity increases. This finding has important implications for developing policy measures that help retirees with making rational financial decisions.

Key words: Annuity Puzzle, Self-annuitization, Probability of Ruin, Properties.

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[a] 1st author, Kyung Hee University, School of Management, Department of Business, Ph.D student. ldhc9@khu.ac.kr.
[b] Corresponding author, Kyung Hee University, School of Management, Department of Business, Graduate student. qwerasty@khu.ac.kr.
[c] Co-author, Professor of Kyung Hee University, School of Management, Department of Business. jhsung@khu.ac.kr.

1. Introduction

In recent decades, “Annuity Puzzle” has been one of the most interesting research subjects in the field of pension finance and actuarial science. Increase of life expectancy and decrease of retirement age have clearly extended post-retirement life of the retirees. Longevity risk, a risk of living longer than expected, then became an important factor that influences significantly on the financial decisions of retirees. As Yaari (1965) showed, it is optimal for retirees to annuitize their wealth under certain conditions. Most of the retirees, however, still prefer receiving a lump-sum payment to receiving annuity. This is apparently a “puzzle”, given the fact that a regular payment would protect their income security after their retirement, and also minimize their ruin risk before they die.

So far, there has been an enormous amount of related literature regarding annuity puzzle. Following on the Yaari’s seminal paper on annuities and the individual’s decision, numerous studies have reported a variety of reasons for why individuals choose to receive lump-sum payments rather than annuities. Four factors have been mainly discussed as determinants that play a significant role in reducing the demand for annuities; pre-annuitized wealth levels, actuarially unfair prices of the annuity products, bequest motives, and uncertain health expenses.

First, Dushi and Webb (2004) have suggested that existing of pre-annuitized wealth levels, such as those by social securities or DB pensions may drop the demand for annuity purchases. This is also supported by Pashchenko (2013), who has shown that the pre-annuitized wealth is the most quantitatively important factor which affects the retiree’s decision.

Second, Mitchell et al. (1999) and Rothschild (2008) have identified that the annuity

puzzle might be attributable to the actuarially unfair prices of the annuity products due to the adverse selection. In the annuity market, insurance premiums should be set high because an individual who voluntarily purchase the annuity products would be healthier and live longer than average. According to Walliser (2000), adverse selection raises annuity price by 7-10 percent. This actuarially unfair prices of the annuity products make them less attractive, crowding out the demand for them.

Third, bequest motives would lower demand for annuities, as Friedman & Warshawsky (1990) have suggested that bequests would serve as an effective annuity products with less default risk for retirees if they live longer than their average lifespan. In other words, retirees choose to bequeath because they expect to support themselves by relying on their heirs until they die. As so, bequest motives may reduce the uninsured risk for retirees. Bernheim (1991) and Laitner & Juster (1996) also have found coherent results about bequest motives. Furthermore, Lockwood (2012, 2016) have argued that the bequest motives would affect demand for the annuity products negatively by reducing the opportunity cost of precautionary saving.

Fourth, Turra & Mitchell (2008) and Pang & Warshawsky (2010) have demonstrated that the retirees would face borrowing constraints, since the annuity products are not able to be sold or borrowed. Therefore, if they encounter any health problem that requires a large amount of money, they will have difficulties with this liquidity problem. Peijnenburg, Nijman, and Werker (2011a) also have suggested that medical expenditure risk might lower the demand for annuities, and Daniel (2012) have found empirical evidence on this health expenditure risk. However, Peijenburg, Nijman, and Werker (2011b) have argued that despite the existence of medical expenditure risk, it is still optimal to fully-annuitize their wealth.

Other factors also have been suggested to explain the annuity puzzle. Horneff et al. (2008a) and Koijen et al. (2011) have found that incompleteness of the annuity market would make retirees become reluctant to purchase them, since the annuity products do not hedge inflation risk as they provide the payouts in nominal value. If nominal annuities are only available in the annuity market, retirees cannot maintain their stable consumption patterns as the real value of the payouts will gradually decrease. Besides, such incomplete annuity products would incur welfare costs to retirees.

Brown (2001) has extensively examined household decisions about annuitization using dynamic programming techniques. Mortality risk, marital status, risk aversion, and presence of pre-existing annuities affect value of the annuities of the retirees. Married retirees relatively tend to prefer annuities than single retirees because of the pooling effect of their mortality risks. This result is in concordance with Kotlikoff & Spivak (1981). He also has shown that retirees with bad health status are significantly less likely to annuitize. Bequest motives, however, did not seem to have significant effects on retirees in his paper. Hurd (1987, 1989) also have demonstrated that bequest motives cannot clearly explain the annuity puzzle. These findings are in direct opposition to the studies mentioned above.

Meanwhile, Hu & Scott (2007) have attempted to figure out the annuity puzzle by behavioral explanation. They adopted the concept of 'mental accounting' and 'loss aversion', which make retirees do not consider the annuity products with their total retirement lifespan. They have claimed that the retirees recognize the annuity products as risky gambles rather than insurance instruments where loss aversion affects them to feel larger potential losses than potential gains, resulting in unpopularity of annuities.

In Korea, we can easily find the annuity puzzle in the retirement market. According to

the 'Retirement Pension Status Report' in the 3rd quarter of 2016 by Financial Supervisory Service, only 1.6% of the retirees chose to receive their retirement benefits as annuities, while 98.4% chose to receive in a lump-sum amount. Then, one might ask that in which asset the retirees invest their money instead of buying whole-life annuities to achieve self-annuitization after their retirement. We find that there exists an uncommon number in the composition of household wealth in Korea (see [Table 1]). Unlike other countries, properties (real estates) account for the largest part (74.0%) of the total household net wealth. This is an exceptionally higher number compared to US (34.94%), UK (55.26%), Japan (43.72%), and Canada (56.74%)[1]. Furthermore, it is even higher if we limit the scope of the household on the age above 60 (82.0%). This means that retirees in Korea particularly tend to prefer holding their assets as properties to other investment options such as stocks, bonds, or deposits.

[Table 1] Household Wealth by Head of Household's Age

(Units: euros, %)

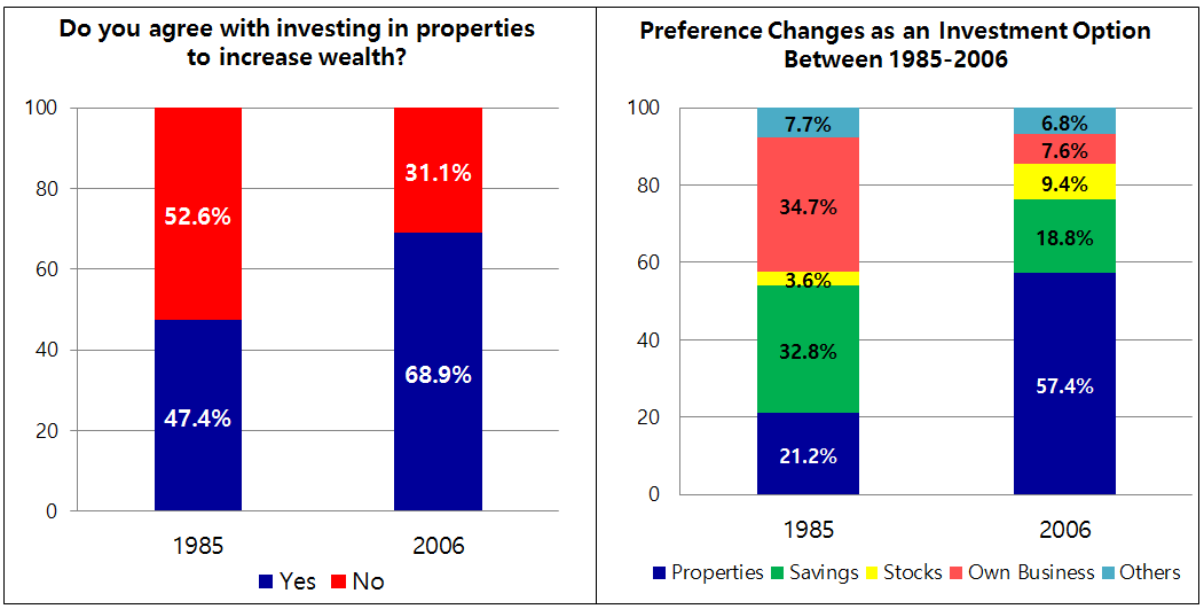
Asset Category / Age	Assets	Financial Assets				Non-Financial Assets				
			% of Assets	Savings	Deposit for Lease & Rent		% of Assets	Properties	residence	Others
Total	227,960	72,203	26.0	53,323	18,880	205,764	74.0	192,253	109,411	13,511
Under 30	67,210	42,078	62.6	16,061	26,009	25,141	37.4	20,455	16,084	4,686
30-39	197,637	74,001	37.4	38,790	35,203	123,644	62.6	111,608	77,941	12,036
40-49	280,855	85,615	30.5	59,744	25,870	195,241	69.5	178,549	109,449	16,691
50-59	340,293	87,189	25.6	72,119	15,071	253,103	74.4	234,676	122,968	18,427
60 or above	281,501	50,558	18.0	43,076	7,489	230,943	82.0	222,570	121,263	8,373

* All euros were rounded off to the nearest integer.
** Source: Survey of Household Finances and Living Conditions (2016), Statistics Korea.

[1] OECD, 2016, *OECD Economic Outlook*, Vol. 2016 Issue 2, 296

This unusual predisposition in properties might be explained by the property bubbles appeared in the early 2000s in Korea. After bailout from IMF in 1998, Korean government reduced the regulatory burdens for properties to boost the economy, including tax relief and loosening restriction on transactions. As a result, the property prices increased significantly in the early 2000s, especially in Seoul and the regions around Seoul. The real estate sales price from 2000 to 2005 in Korea increased 37.9%; for Seoul and the regions around Seoul, it was 59.1% and 54.8% for the same period. Presumably, this higher growth rate of prices in the real estate market in Korea might have led to a high propensity for properties among Koreans. In 2006, a relevant survey was conducted by Korea Research Institute for Human Settlements. There are 2 questions about the preference to properties: 1) Do you agree with investing in properties to increase wealth? 2) What is your priority among investment options if you have extra money? The result is presented in [Figure 1].

[Figure 1] Survey Results Comparison between 1985 and 2006



* Source: The Survey on People's Awareness of Land (2006), Korea Research Institute for Human Settlements.

In the first question, 68.9% of respondents said 'yes'. It indicates that people in Korea became less reluctant about investing in properties compared to 1985. Furthermore, the results in the second question clearly shows that more than half of the respondents chose properties as their favorable investment option, whereas only 21.2% regarded it as an effective investment in 1985. Thus, it is obvious that Korean people have been disposed to purchase properties as their investment option rather than other investment method.

In this paper, we aim to examine probability of ruin (hereinafter referred to as PoR) when a worker invests in several asset categories during his or her lifetime, particularly focusing on the role of properties. The aging problem is the fastest in Korea among developed countries, which might aggravate the longevity risk and the PoR of the retirees. Thus, it is of great importance for retirees to identify a rational financial decision-making that helps their retirement wealth not to be depleted during the post-retirement life. With the strong propensity for properties among Koreans, we expect to find evidence for why Korean workers are not willing to purchase the whole-life annuities. We set three scenarios that retirees would take as their asset allocation strategies at retirement. Then we compare the PoR of each scenario to identify the optimal asset allocation.

The remaining part of the paper proceeds as follows. Section 2 begins by introducing the assumptions and research methodology used in simulation. It will then go on to explain the result of the simulation in section 3. Finally, the last section gives conclusion with a brief summary and critique of the findings.

2. Assumptions and research methodology

2.1 Assumptions for analysis

This paper attempts to figure out the inclination of Korean workers' behavior that invest primarily to properties by examining PoR of a person with specific asset allocation strategies during his or her lifetime. The assumptions for analysis are set as follows.

- Assumption 1: Asset accumulation of a worker starts from age 30 and net income is invested annually by three asset categories; financial assets, properties, and pension assets. Financial assets consist of domestic stocks and deposits.[2]

[Table 2] Historical Data of Financial Assets, Properties, and Pension Assets

(Units: %)

Year	Financial Assets		Properties	Pension Assets[1)]
	Domestic Stocks	Deposits		
2001	37.47	6.21	9.87	-
2002	-9.54	6.26	16.43	-
2003	29.19	4.76	5.74	5.92
2004	10.51	4.35	-2.07	5.47
2005	53.96	4.52	4.01	3.96
2006	3.99	4.96	11.60	4.65
2007	32.25	5.28	3.14	8.81
2008	-40.73	5.36	3.11	4.15
2009	49.65	4.64	1.46	5.67
2010	21.88	4.31	1.89	5.75

[2] We do not include bonds in financial assets. According to the Survey of Household Finance and Living Conditions (2016), 91.6% of households in Korea prefer deposits as a way of financial asset management and 4.0% of them choose stocks; no respondents choose bonds. In addition, households are also asked to state where to invest their money if their income increased or they have some extra money. 43% of respondents choose financial assets while 27.8% choose properties; 23.6% choose debt-repayment. Thus, we set three asset categories as mentioned above including pension assets.

2011	-10.98	3.90	6.86	3.16
2012	9.38	3.24	-0.03	4.35
2013	0.72	3.00	0.37	2.53
2014	-4.76	2.83	2.10	3.57
2015	2.39	1.97	4.42	2.65
2016	3.32	1.53	1.35	-
Average	11.79	4.20	3.75	4.67
Standard Deviation	23.78	1.33	4.64	1.63

1) We use the rate of return of Investment Pool for Public Funds for the pension assets. However, the data is not available in 2001, 2002, and 2016.
* Source: Bank of Korea, KB Financial Group, Investment Pool for Public Funds.

- Assumption 2: Workers are categorized by income quintiles, and the average income for each quintile is set as [Table 3]. Income increases annually by the average wage growth rate based on average growth rate of negotiated wages from 2007 to 2015 in Korea (see [Table 4]). Here, we do not distinguish between income and wage. In other words, there is no additional income for all workers other than wage.

[Table 3] Households Total Monthly Income and Expenditure for Each Quintile

(Units: euros)

Quintiles	1st quintile	2nd quintile	3rd quintile	4th quintile	5th quintile
Income	1,088	2,231	3,092	4,095	6,564
Expenditure	981	1,544	1,905	2,308	3,167

* All numbers were rounded off to the nearest integer.
** Source: Household Survey Data in 3rd quarter of 2016, Statistics Korea.

[Table 4] Wage Growth Rate from 2007 to 2015[1)]

(Units: %)

Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	**Average**
Growth Rate	6.26	5.54	1.15	2.97	3.47	5.33	3.13	2.80	2.82	**3.72**

1) We use the data from 2007 to 2015, because the wage data prior to 2007 is currently not available.
* Source: Ministry of Employment and Labor (http://www.laborstat.molab.go.kr).

- Assumption 3: Consumption level of each worker is provided as the average expenditure for each quintile in [Table 3] and increases annually by the inflation rate, based on the average inflation rate from 2001 to 2016 in Korea (see [Table 5]). In addition, considering the fact that retirees tend to spend less money after retirement, we set three maintenance rates of the consumption level (100%, 70%, and 50%). For example, a 70% maintenance rate means that a retiree at age 55 will spend 70% of the consumption amount he spent at age 54.

[Table 5] Inflation Rate from 2001 to 2016

(Units: %)

Year	2001	2002	2003	2004	2005	2006	2007	2008
Inflation Rate	4.1	2.8	0.5	3.6	2.8	2.2	2.5	4.7
Year	2009	2010	2011	2012	2013	2014	2015	2016	**Average**
Inflation Rate	2.8	2.9	4	2.2	1.3	1.3	0.7	1.0	**2.46**

* Source: Statistics Korea (http://www.index.go.kr).

- Assumption 4: Workers participate in defined contribution (DC) plan, making yearly contributions at the beginning of each year during their continuous years of service. The contribution amount is determined as 1/12 of the wage every year.[3]

- Assumption 5: Workers are supposed to retire at age 55[4] at which they make financial decisions as following scenarios. Workers will receive the pension amount annually by assumed interest rate if they choose to purchase whole-life

[3] In Korea, Employee Retirement Benefit Security Act requires employers of DC plan to make yearly contributions of their employees at least 1/12 of each employee's wage.

[4] In Korea, the Employee Retirement Benefit Security Act regulates minimum pensionable age as 55.

annuities, while workers who decide to self-annuitize will receive annual returns by the asset allocation strategies they choose. There are 3 scenarios of financial decisions. The scenarios are given below in [Table 6].

[Table 6] Financial Decision Scenarios of Workers at Retirement

Asset Category	Pension Assets	Financial Assets	Properties
Scenario 1	Self-annuitization		
Scenario 2	Whole-life annuity	Self-annuitization	
Scenario 3	Whole-life annuity		

- Assumption 6: Workers have two principles regarding their asset allocation strategies as follows. First, they choose asset allocation strategy that maximizes Sharpe ratio while accumulation period. After retirement, however, they choose asset allocation strategy that minimizes the PoR.

2.2 Research methodology

We examine the optimal asset allocation of both the accumulation period and the post-retirement period by using portfolio that maximizes the Sharpe ratio and minimizes the PoR for each period.

1) Accumulation period: portfolio that maximizes the Sharpe ratio

In accumulation period, workers take the asset allocation strategy that maximizes risk-adjusted return by using mean-variance model. The optimal portfolio can be drawn by the mean-variance model that incorporates expected return of an asset and its correlation with others, simply called as efficient frontier. Further, if we are able to borrow a risk-free asset with no limits, higher return is possible by investing in risk-free asset and perfectly diversified risk assets. Sharpe ratio is a measure for risk-adjusted

return, calculated by subtracting return of the risk-free asset from return of a risky asset, then dividing it by standard deviation of the risky asset.

Assume that a portfolio is composed of *n* risky assets and the weight of each asset is $\{w_1, w_2, \cdots, w_n\}$. Let $\mathrm{E}\left[\left(r_p(t)\right)\right]$ represents the expected return of a portfolio; $\sigma\left[\left(r_p(t)\right)\right]$ the standard deviation of a portfolio; $\sigma\left[\left(r_i(t)\right)\right]$ the standard deviation of an asset *i*; $r_f(t)$ the return of a risk-free asset. Then the Sharpe ratio is calculated as follows:

$$\mathrm{SR} = \frac{E[r_p(t)] - r_f(t)}{\sigma[r_p(t)]},$$

$$\text{where } \sum_i w_i = 1 \text{ and } w_i \geq 0$$

2) Post-retirement period: portfolio that minimizes the probability of ruin

If a worker choose to self-annuitize, the value of the worker's assets might be declined to zero until his death. This risk can be defined as ruin risk. Abrecht and Maurer (2001) first suggested PoR, which reflects the ruin risk combined with the survival probability of each age. Let T_x represents the remaining lifetime of a retiree aged *x* at time t=0; τ_R the earliest time-point at which the exhaustion of the retiree's wealth occurs. Then PoR is defined as follows:

$$\mathrm{PoR} = \mathrm{P}(T_x > \tau_R)$$

Let ${}_t\mathrm{P}_x$ represents the probability of a retiree aged x that survives until time $(x + t)$ and ω denote the lifespan. Provided that T_x and τ_R are stochastically independent, PoR is also defined as follows:

$$\text{PoR} = \sum_{t=0}^{\omega-x} {}_t\text{P}_x \cdot \text{P}(\tau_R = t)$$ [5]

Here, τ_R must be determined by a simulation method because it is related to various paths of asset value fluctuations that requires numerical analysis. Let W(t) represent the asset value of a retiree from the initial wealth at the retirement, where the consumption amount R is annually made. Also let i_t denote the rate of return at time t, then we can define the growth model of the asset value as follows:

$$W_1(t) = \begin{cases} (W_0(t) - R)(1 + i_t) & if\ W_0(t) > R \\ 0 & if\ W_0(t) \leq 0 \end{cases}$$

$$\text{where } \text{W}_0(\text{t}) = \text{W}_1(\text{t} - 1)$$

The time that the asset exhaustion occurs depends on the consumption amount (R) and the rate of return(i_t). In the case of self-annuitization, asset categories are set as domestic stocks, deposits, and properties as mentioned earlier. The rate of return (i_t) is determined by the geometric Brownian motion (GBM). Let $S_i(\text{t})$ represent the price of asset *i* at time t; μ_i the average rate of return of asset *i*; σ_i the standard deviation of asset *i*; $\in_i$ the Wiener process of asset *i*, then GBM is defined as follows:

$$\frac{S_i(t + \Delta t)}{S_i(t)} = \exp\left[\left(\mu_i - \frac{1}{2}\sigma_i^2\right)\Delta t + \sigma_i \epsilon_i \sqrt{\Delta t}\right], \epsilon_i \sim N(0,1)$$

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[5] Here is a proof of the equation.

$$\begin{aligned} \text{P}(T_x > \tau_R) &= \text{P}(T_x - \tau_R > 0) \\ &= \sum_{t=0}^{\infty} \text{P}(T_x - t > 0 | \tau_R = t) \cdot \text{P}(\tau_R = t) \\ &= \sum_{t=0}^{\infty} \text{P}(T_x > t) \cdot \text{P}(\tau_R = t) \\ &= \sum_{t=0}^{\infty} {}_t\text{P}_x \cdot \text{P}(\tau_R = t) \\ &= \sum_{t=0}^{\omega-x} {}_t\text{P}_x \cdot \text{P}(\tau_R = t). \end{aligned}$$

For a complete derivation of the equilibrium, including the structural and technical assumptions, see Appendix B in Albrecht and Maurer (2001).

Therefore, i_t is presumed by stochastic model. In this paper, we run 10,000 times of simulations for each scenario by employing stochastic model that incorporates the correlations between investment assets. We use the Cholesky decomposition method to reflect the correlations.

Minimizing PoR strategy is to allocate assets on the way that minimizes the PoR. However, it is impossible to clearly determine the mathematical logic of τ since it is a random variable that affected by the uncertain value of several assets. Thus, we employ genetic algorithm. The genetic algorithm is stochastic search algorithm that replicate the evolution mechanisms of nature, first introduced by John Holland in 1970s. It aims to find exact or approximate solutions to optimization and search problems (Scrucca, 2013).

To find the optimal ratio of the three assets that minimizes the PoR, a scalar-valued objective function $f: \mathrm{S} \to \mathbb{R}$ can be structured as a problem of finding the set

$$\Theta^* = \arg\min_{\theta \subseteq \Theta} f(\theta) = \left\{\theta^* \in \Theta : f(\theta^*) \leq f(\theta),\ \forall \theta \in \Theta\right\},$$

where $\Theta \subseteq S$ and the set $\mathrm{S} \subseteq \mathbb{R}^3$ denote the search space. The variables $\theta = (\theta_1, \theta_2, \theta_3)$ are determined between 0 and 1 under constraint of $\sum \theta_i = 1$, and the set Θ represents the available search space. The solution set Θ^* may include a specific single solution or countable solutions, or may have unlimited number of solutions. Genetic algorithms can be used to solve the optimization problem in both continuous and discrete model (Spall, 2004). Hence, we examine the optimal portfolio using the genetic algorithms.

2.3 Calculating annuity payment

Immediate life annuity is an annuity contract that a retiree can purchase with a single lump-sum payment and receive a regular payment until it terminates upon death of the retiree. Thus, an immediate life annuity can be a great mean of stabilizing post-retirement life for retirees who are making their living only by their savings account without any additional income. In this paper, we set an immediate life annuity as a mean of whole-life annuity, which has no delay period of payments. Let P_0 represent the single premium of the annuity; α the rate of acquisition costs; β the rate of renewal commission; λ the rate of management expenses per year; r^* the interest rate on a product; ω the maximum lifespan; and ${}_tP_x$ the survival rate of a retiree aged x at time $(x+t)$. Then, the payout amount for an immediate life annuity (A_0) can be calculated as follows:

$$A_0 = \left[\frac{(P_0 \times (1-\alpha-\beta)}{\sum_{t=0}^{\omega-x}(1+r^*)^{-t} \times {}_tP_x}\right] \div (1+\lambda)$$

We use the data of three biggest life insurance companies in Korea. The rate of acquisition costs, the rate of renewal commission, interest rate on product, and the rate of management expenses per year for each annuity product is presented in [Table 7]. The sum of α and β is 7% for all products, however, the interest rate on product and the rate of management expenses per year are different.

[Table 7] Total Operating Cost and Interest Rate on Immediate Life Annuity Products

Annuity Product	Rate of acquisition costs	Rate of renewal commission	Interest rate on a product	Rate of management expenses per year
A	5.00% of premium	2.00% of premium	2.48%	1.20%
B	4.50% of premium	2.50% of premium	2.50%	0.60%
C	4.60% of premium	2.40% of premium	2.52%	0.70%
Average	7.00% of premium		2.50%	0.83%

* Source: Policy manuals for each annuity product (Dec. 2016).

In this article, we set the total rate of acquisition costs and renewal commission as 7%; interest rate on a product as 2.50%; and rate of management expenses per year as 0.83% based on the average rates of three annuity products. The payout amount for an immediate life annuity is varied by the interest rate on the product, however, we assumed that the payout amount is fixed for all period.

3. Results

To identify the annuity puzzle in Korea, we analyze optimal asset allocation for each income quintile. Every worker's life is divided into the two periods on the basis of the retirement point; the accumulation period and the post-retirement period. We particularly focus on minimizing the PoR in the second period.

3.1 Accumulation period

As we assumed above, a worker receives a regular income from the age 30 to 55 and this term of period is defined as the accumulation period. A worker's income and consumption are generated annually at the beginning of each year. Net income, the income subtracted by the consumption, is invested into the financial assets and

properties by optimal asset allocation which maximizes the Sharpe ratio. However, there is no asset-rebalancing during the accumulation period. [Table 8] displays the result of the asset allocation that maximizes Sharpe ratio.

[Table 8] Optimal Asset Allocation in the Accumulation Period

(Unit: %)

Financial Assets		Properties	Pension Assets	Total
Domestic Stocks	Deposits			
14.00	4.85	72.82	8.33	100.00

* Source: Authors' calculations.

In [Table 8], properties play a key role in the optimal asset allocation. It accounts for 72.82% of the total asset allocation, greatly higher than the other asset categories. Despite the fact that the risk-return profile of the properties is inferior to that of deposits, the properties still remain significant since it provides some hedge against investment risk of the stocks[6]. This explains why the properties have been a great mean of investment alternatives in Korea. Thus, the strong propensity for properties among Koreans has been rather a rational financial decision.

3.2 Post-retirement period

Post-retirement period refers to as a time from a worker's retirement until his death. Only consumption is generated at the beginning of every year during this period.

[6] Correlations among the investment assets are as follows.

	Domestic Stocks	Deposits	Properties
Domestic Stocks	1	0.18	-0.11
Deposits	0.18	1	0.57
Properties	-0.11	0.57	1

Therefore, it is highly important for retirees to manage ruin risk since they use the amount of accumulated assets without any income. Thus, we examine the optimal asset allocation of the retirees by identifying asset allocations that minimizes the PoR. The optimal asset allocation for each income quintile is calculated differently because the PoR directly depends on the accumulated assets and the consumption level of retirees. With this approach, we can examine the annuity puzzle in more detail with every income quintile of retirees. [Table 9] shows the amount of accumulated assets for each quintile at the retirement age managed by the asset allocation of [Table 8].

[Table 9] Accumulated Assets at Retirement Age

(Units: euros)

Asset Categories	1st quintile	2nd quintile	3rd quintile	4th quintile	5th quintile
Retirement pension	73,091	149,803	207,656	274,995	440,810
Domestic Stocks	33,753	206,183	352,383	518,036	995,484
Deposits	8,983	44,182	73,990	108,661	204,438
Properties	81,099	394,344	659,558	968,415	1,819,827

* All numbers were rounded off to the nearest integer.
** Source: Authors' calculations.

The retiree's asset in post-retirement period consists of a whole-life annuity and self-annuitized asset. Generally, various factors such as bequest motives, payout amount of annuity, and health status should be considered when determining the ratio between two assets. However, we set 3 scenarios to put it in the simplest way; 100% self-annuitization (scenario 1), buying a whole-life annuity by pension assets and self-annuitization for the financial assets and properties (scenario 2), and purchasing a whole-life annuity for all assets amount (scenario 3). Then we calculated both the optimal asset allocation and the PoR.

1) Scenario 1

[Table 10] shows the asset allocation and PoR by minimizing PoR strategy when a worker self-annuitizes all of his assets. Overall, PoR tends to decrease as the income quintile increases and the maintenance rate decreases. This indicates that the amount of assets and maintenance rate is closely related to the PoR.

[Table 10] Asset Allocation and PoR of Scenario 1

(Units: %)

Maintenance Rate	Asset	Income quintile				
		1st quintile	2nd quintile	3rd quintile	4th quintile	5th quintile
100%	Domestic Stocks	92.49	64.11	6.62	3.06	10.01
	Deposits	7.50	35.80	93.30	96.74	83.66
	Properties	0.01	0.09	0.07	0.20	6.34
	PoR	69.73	17.82	0.97	0.00	0.00
70%	Domestic Stocks	91.86	3.77	6.62	12.55	20.65
	Deposits	8.12	95.92	93.37	79.73	42.90
	Properties	0.02	0.31	0.01	7.72	36.45
	PoR	47.12	0.09	0.00	0.00	0.00
50%	Domestic Stocks	89.56	7.69	17.20	23.54	24.20
	Deposits	8.50	91.39	52.82	42.54	36.07
	Properties	1.94	0.92	29.98	33.92	39.73
	PoR	28.55	0.00	0.00	0.00	0.00

* Sum of asset allocation percentages may equal 100%.
** Source: Authors' calculations.

Provided that the maintenance rate is constant, we can see that the retirees in higher income quintile should invest primarily in riskless assets, whereas retirees in lower income quintile should invest majority of their money in risky assets. It means that the high-income workers are able to support their cash flows for their consumption during post-retirement period by a low-risk, low-return investment strategy; however, low-

income workers should put their assets in domestic stocks to sustain their consumption.

In addition, it appears that if a retiree in higher income quintile reduces the maintenance rate, they are not only able to manage ruin risks, but invest in a wide selection of assets as well. In particular, the asset allocation for properties increases significantly. This indicates that it might be a rational financial decision for some retirees to invest highly in properties in perspective of minimizing PoR. On the contrary, however, it shows that retirees in middle and lower income quintile should put their money mainly in deposits and domestic stocks. Thus, retirees should set different asset allocation strategies after retirement, considering both the amount of their assets and the consumption level.

2) Scenario 2

[Table 11] provides the asset allocation and PoR by minimizing PoR strategy when a worker purchases a whole-life annuity by pension assets and self-annuitizes financial assets and properties. Compared to scenario 1, the asset allocation ratio of deposits relatively decreases in scenario 2. This can be interpreted as the role of deposits that provides a stable cash flow is substituted with the whole-life annuity.

[Table 11] Asset Allocation and PoR of Scenario 2

(Units: %)

Maintenance Rate	Asset	Income quintile				
		1st quintile	2nd quintile	3rd quintile	4th quintile	5th quintile
100%	Domestic Stocks	91.43	85.15	5.88	3.87	12.42
	Deposits	7.80	14.83	94.09	95.93	77.07
	Properties	0.77	0.02	0.03	0.20	10.51
	PoR	85.58	19.24	0.00	0.00	0.00

70%	Domestic Stocks	90.88	3.90	7.25	13.96	22.56
	Deposits	8.78	95.93	91.45	63.44	34.57
	Properties	0.34	0.17	1.30	22.60	42.87
	PoR	63.56	0.10	0.00	0.00	0.00
50%	Domestic Stocks	90.73	9.78	20.93	22.32	32.65
	Deposits	9.15	76.54	44.41	38.30	28.63
	Properties	0.12	13.68	34.66	39.38	38.72
	PoR	37.13	0.00	0.00	0.00	0.00

* Sum of asset allocation percentages may equal 100%.
** Source: Authors' calculations.

In respect to PoR, the ruin risk is lower when self-annuitizing all assets.[7] Particularly, we can compare a worker in the 1st income quintile with the maintenance level of 100%. The PoR is 69.73% in scenario 1, however, it shoots up to 85.58% if a worker buys a whole-life annuity. This indicates that cash flow from a whole-life annuity hardly overwhelms that of self-annuitization. Therefore, self-annuitization outcompetes purchasing a whole-life annuity in perspective of the ruin risk.

3) Scenario 3

[Table 12] presents the PoR when a worker purchases a whole-life annuity by all of his assets at the retirement. The ruin risk is not occurred in scenario 3 since the payout amount from a whole-life annuity is regularly generated for every period. Thus, we redefined ruin risk as a probability that the payout of the annuity does not exceed the amount of consumption. As a result, the ruin risk is not found in the 3rd, 4th, and 5th

[7] We are not able to compare PoR of 3rd, 4th, and 5th income quintile since no ruin risk is occurred both in scenario 1 and 2. Looking at the 1st and 2nd income quintile, PoR is higher in case of purchasing a whole-life annuity.

income quintile if a worker maintains the consumption level as same as before his retirement. Furthermore, there is no ruin risk except the 1st income quintile[8] in case of reducing the maintenance level after retirement. Hence, buying a whole-life annuity can be an effective way of hedging the ruin risk, especially when a retiree curtails the consumption level.

[Table 12] PoR of Scenario 3

(Units: %)

Maintenance Rate	Income quintile				
	1st quintile	2nd quintile	3rd quintile	4th quintile	5th quintile
100%	100.00	90.77	0.00	0.00	0.00
70%	100.00	0.00	0.00	0.00	0.00
50%	100.00	0.00	0.00	0.00	0.00

* Source: Authors' calculations.

However, the overall analysis of the results shows that the self-annuitization takes advantage over the purchasing a whole-life annuity regarding PoR. [Table 13] shows the PoR of each scenario and consumption level. The PoR of lower income quintile increases as the amount of whole-life annuity increases. However, we cannot exactly examine the superiority between two strategies for retirees in 3rd, 4th, and 5th quintile because the PoR is zero regardless of all scenarios. In general, self-annuitization is thought to be superior to purchasing annuity products considering certain factors such as liquidity of assets or bequest availability.

[8] PoR of 1st quintile is zero when the consumption level dropped by 30%.

[Table 13] PoR of All Scenarios for Each Maintenance Rate

(Units: %)

Maintenance Rate	Scenario	Income quintile				
		1st quintile	2nd quintile	3rd quintile	4th quintile	5th quintile
100%	Scenario 1	69.73	17.82	0.00	0.00	0.00
	Scenario 2	85.58	19.24	0.00	0.00	0.00
	Scenario 3	100.00	90.77	0.00	0.00	0.00
70%	Scenario 1	47.12	0.10	0.00	0.00	0.00
	Scenario 2	63.56	0.10	0.00	0.00	0.00
	Scenario 3	100.00	0.00	0.00	0.00	0.00
50%	Scenario 1	28.55	0.00	0.00	0.00	0.00
	Scenario 2	37.13	0.00	0.00	0.00	0.00
	Scenario 3	100.00	0.00	0.00	0.00	0.00

* Source: Authors' calculations.

4. Conclusions

In Korea, financial planning for retirees has been focused only on the accumulation of assets. It can be a good measure of evaluating investments during the accumulation period at which the cash flows of workers are continuously generated. However, a different approach should be adopted after retirement because the most important issue in the post-retirement period is how to transfer the accumulated assets to a continuous flow of consumption. Notwithstanding, there has seldom been concrete discussions about how to achieve this crucial point so far. Furthermore, it is obvious that the longevity risk and the PoR of retirees in Korea will be exacerbated by the rapid drift of population ageing. Therefore, it is of great significance to manage accumulated assets not to be exhausted so that the retirees are able to make their livings without ruin after retirement.

In this paper, we analyze the annuity puzzle that most of workers in Korea choose to receive lump-sum amount of money rather than annuitization. We compare asset

allocations of three scenarios in perspective of minimizing PoR; self-annuitization, buying a whole-life annuity and mixed strategy. In most cases, PoR depends on consumption amount, asset allocation and expected lifespan. To be more specific, PoR is negatively affected by the higher consumption amount, lower rate of return on investment, and longer expected lifespan.

We set the asset allocation portfolio with domestic stocks, deposits, and properties. Expenditure amount of each income quintile of households in Korea is used as a benchmark for annual withdrawal. Also, we employ survival rate of male from the 7th experience life table for 2012-2015 and the retirement age is assumed as 55. Main findings from the simulations are described as follows.

Firstly, the weight of properties in the asset allocation was significantly high in the case of maximizing Sharpe ratio. It seems that properties can give some hedge against the risk of domestic stocks in the portfolio. Secondly, the asset allocations for minimizing PoR varied by the income quintiles. This is because the returns on investment to meet the amount of consumption that retirees need are differed by the income quintiles. Thirdly, the PoR increased significantly as the amount of a whole-life annuity increases. It is probably due to the fact that payout amount of a whole-life annuity hardly beats the cash flow generated by self-annuitization.

These findings have important implications for designing financial planning for retirees. One of the issues emerging from these findings is that we should consider an individual's financial status from various angles in evaluating financial decisions rather than rely solely on the same standard for all workers. In other words, fundamental approach of how we can manage risks that a retiree faces after retirement should be changed. In addition, the evidence from this study suggests that self-annuitization might

be more efficient for retirees in minimizing PoR, which gives a plausible explanation for the annuity puzzle in Korea. In some cases, properties play a key role in the asset allocation of retirees, particularly if a retiree chooses to reduce his consumption level after retirement.

Managing retirement assets at the discretion of retirees by self-annuitization strategy has some advantages over buying a whole-life annuity such as asset liquidity, bequest availability, and higher level of consumption. However, the ability to make financial decision properly with considering their financial status is essentially required for retirees. In this paper, we assumed that the asset allocation is determined by the minimizing PoR strategy so that the ruin risk can be controlled in some degree. Recent studies on financial behavior of individuals, however, demonstrate that the individuals often are not rational in financial decision-making (Samuelson and Zeckhauser(1988), Lucas(2000), Brown et al.(2008)). Thus, policymakers should make efforts to develop policy measures that help retirees with making rational financial decisions which are deemed essential for the post-retirement life.

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