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Comparison of Projected Unit Credit and Entry Age Normal Methods in Sharia Pension Fund Financing using the Cox Ingersoll Ross Investment Return Model

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ABSTRACT

This research is motivated by the low level of pension fund planning in Indonesia and the importance of selecting an appropriate actuarial method to determine contributions and liabilities in a manner consistent with Sharia principles. Calculations were performed to determine normal contributions and actuarial liabilities using the Projected Unit Credit (PUC) and Entry Age Normal (EAN) methods, incorporating a discount factor derived from the Cox Ingersoll Ross (CIR) model to represent stochastic Return on Investment (RoI). The results indicate that the PUC method yields normal contributions that increase with the participant's age, whereas the EAN method produces contributions that remain relatively constant throughout the employment period. Regarding actuarial liabilities, the PUC method results in lower initial values that increase gradually, while the EAN method generates higher liabilities from the start of the participation period. From the participant's perspective, the EAN method is more favorable as it imposes a more stable and lighter contribution burden. Conversely, from the perspective of the company or pension fund manager, the PUC method is more advantageous due to the lower initial actuarial liability burden. Furthermore, the use of the CIR model provides a more realistic estimate of investment returns by accounting for stochastic and mean reverting characteristics, thereby resulting in more accurate calculations of the present value of pension benefits.

Keywords: Sharia Pension Fund, Projected Unit Credit, Entry Age Normal, Normal Contribution, Actuarial Liability.

1. INTRODUCTION

Financial planning is a crucial aspect of securing future well being, particularly in preparation for retirement. However, public awareness in Indonesia regarding the importance of retirement planning remains relatively low. A survey by the Financial Services Authority (OJK) indicates that only about 30% of workers in Indonesia have a retirement plan [1]. Low financial literacy, consumerist behavior, and a lack of saving and investment habits result in many individuals lacking financial readiness upon reaching retirement age [2]. Consequently, most retirees rely solely on savings or pension funds that are often insufficient to meet living expenses, especially given the rising costs of healthcare and living in old age [3].

A Sharia pension fund is a program or service offered by a legal entity with the aim of providing pension benefits based on Sharia principles, in accordance with applicable legal provisions [4]. Pension fund programs serve as a vital instrument for ensuring continued income after an individual ceases working. For workers, pension funds not only provide protection against the risk of income decline due to aging but also enhance well being in their later years [5]. With the growth of the sharia financial industry in Indonesia, sharia pension funds have emerged as an alternative managed according to sharia principles, as stipulated in DSN-MUI Fatwa No. 88/DSN-MUI/XI/2013. The primary distinction between sharia pension funds and conventional pension funds lies in the application of contracts and investment mechanisms that align with sharia principles; thus, fund management is conducted without utilizing interest-based instruments.

The only difference between Sharia pension funds and conventional pension funds is that Sharia pension funds utilize Sharia contracts, whereas conventional pension funds do not. Backed by DSN-MUI Fatwa No. 88 of 2013 and OJK Regulation No. 33 of 2016, Sharia pension funds have been operating in Indonesia since 2017 [6].Pension funds are generated from regular contributions made by individuals, employees, and employers into a pension plan, and are subsequently paid out to the beneficiaries of the retiree [7].

In developed countries, there is a significant trend of allocating investment funds to alternative capital, including investments linked to sustainable finance. Pension funds play a role as institutions that directly support the nation's economic sustainability [8]. In the actuarial calculations for conventional pension funds, the discount factor typically employs an interest rate. In contrast, sharia pension funds utilize Return on Investment (RoI) as the basis for calculation [9]. Therefore, a model capable of realistically representing RoI fluctuations is required. The Cox Ingersoll Ross (CIR) model was selected due to its mean reverting property and its ability to yield consistently positive rates of return, making it more suitable for projecting investment returns than the use of a fixed interest rate. A positive Return on Investment (ROI) indicates that all investment costs have been covered and the revenue generated from the investment is sufficient to cover expenses [10].

In actuarial practice, the methods widely used to calculate pension fund financing are the Projected Unit Credit (PUC) and Entry Age Normal (EAN) methods. These two methods different in how they determine normal contribution amounts and actuarial liabilities, there by resulting in different consequences for both pension fund participants and administrators. Previous studies have generally employed a fixed interest rate as the discount factor**.** The amount of participant contributions stipulated in the Pension Fund Regulations and the portion of the Present Value of Pension Benefits allocated to the relevant year are calculated using Actuarial Valuation Methods, specifically the Projected Unit Credit and Entry Age Normal methods [11]. Therefore, this study offers a distinct approach by applying the stochastic Cox Ingersoll Ross (CIR) model to project the Return on Investment for Sharia pension funds, and subsequently comparing the Projected Unit Credit (PUC) and Entry Age Normal (EAN) methods based on normal contribution amounts and actuarial liabilities from the perspectives of both participants and fund managers. The investment return rate or RoI, is subsequently simulated following the estimation of parameters [12]. Given the volatility of interest rates, the change in the interest rate at time t denoted as $r(t)$ with respect to the change in time [13].

Based on this premise, the study aims to analyze and compare the Projected Unit Credit and Entry Age Normal methods in calculating normal contributions and actuarial liabilities for Sharia pension funds utilizing a Return on Investment modeled via the Cox Ingersoll Ross (CIR) framework with the expectation of providing insight into which method is more suitable for the administration of Sharia pension fund programs.

2. METHODS

Data collection was conducted using the documentation method, gathering data on participants of the Ministry of UMKM Pension Fund, the Indonesian Mortality Table (TMI 2019) The primary tool actuaries use to determine premiums and reserves for products such as life insurance, annuities, and pension plans is the mortality table, sometimes referred to as a life table [14], and Historical SBSN data for the period 2023–2026 were obtained from the official website of the Directorate General of Financing and Risk Management (DJPPR), Ministry of Finance of the Republic of Indonesia[15]. All data were subsequently processed using microsoft excel for parameter estimation and actuarial calculations.

The analysis was conducted through the following stages :

a. Salary accumulation, calculated based on the participant’s rank and years of service until retirement age, formulated as:

$$S_r = \sum_{e}^{r-1} S_x \tag{1}$$

b. Determination of pension benefits, based on a certain proportion of the participant's salary at retirement age, formulated as:

$$B_r = kS_r \tag{2}$$

c. Estimation of CIR parameters, including the mean-reversion speed, long-term mean, and volatility, using Sukuk Negara (SBSN) yield data, formulated as:

$$\hat{k} = \frac{n^2 - 2n + 1 + \Sigma_{t=1}^{n-1} r_{t+1} \Sigma_{t=1}^{n-1} \frac{1}{r_t} - \Sigma_{t=1}^{n-1} \frac{1}{r_t} - (n-1)\Sigma_{t=1}^{n-1} \frac{r_{t+1}}{r_t}}{(n^2 - 2n + 1 - \Sigma_{t=1}^{n-1} r_t \, \Sigma_{t=1}^{n-1} \frac{1}{r_t})\Delta t} \tag{3}$$

$$\hat{\theta} = \frac{(n-1)\Sigma_{t=1}^{n-1} r_{t+1} - \Sigma_{t=1}^{n-1} \frac{r_{t+1}}{r_t} \Sigma_{t=1}^{n-1} r_t}{\left(n^2 - 2n + 1 + \Sigma_{t=1}^{n-1} \frac{1}{r_t} - \Sigma_{t=1}^{n-1} r_t \, \Sigma_{t=1}^{n-1} \frac{1}{r_t} - (n-1)\Sigma_{t=1}^{n-1} \frac{r_{t+1}}{r_t}\right)} \tag{4}$$

$$\hat{\sigma} = \sqrt{\frac{1}{n-2} \sum_{t=1}^{n-1} \left(\frac{(r_{t+1} - r_t)}{\Delta t \sqrt{r_t}} - \frac{\hat{\theta}}{\sqrt{r_t}} + \hat{k}\sqrt{r_t} \right)^2} \tag{5}$$

d. Calculation of RoI, based on the estimated CIR parameters, formulated as:

$$R_t = R_{t-1} + \hat{k}\Delta t\left(\hat{\theta} - R_{t-1}\right) + \hat{\sigma}\sqrt{R_{t-1}} dWt + \frac{1}{4} \hat{\sigma} 2_{\Delta t} \tag{6}$$

Before calculating the life annuity value, the discount factor is first calculated using the following formula:

$$v_t = \frac{1}{\left(1 + R(s)\right)}; R(s) > -1 \tag{7}$$

Before calculating the life annuity value, the value of term is also calculated using the following formula:

$$D_x = v^x l_x \tag{8}$$

Then, the life annuity is calculated using the following formula:

$$\ddot{a}_x = \frac{N_x}{D_x} \tag{9}$$

Before calculating the PVFB, the survival function is also calculated using the following formula:

$$_np_x = \frac{l_{x+n}}{l_x} \tag{10}$$

e. Calculation of PVFB, considering pension benefits, survival probability, life annuity, and discount factor, formulated as:

$$^r(PVFB)_x = B_r \ddot{a}_r v^{r-x} {}_{r-x}p_x \tag{11}$$

f. Calculation of normal contributions, using the PUC and EAN methods, formulated as:
Projected Unit Credit **:**

$$^{PUC\,r}(NC)_x = \frac{^{r}(PVFB)x}{r-e} \tag{12}$$

Entry Age Normal :

$$^{r}(NA)_e = \sum_{x-e}^{r-1} \frac{^{r}(NC)_x}{v^{r-x}} \tag{13}$$

g. Calculation of actuarial liabilities, using the PUC and EAN methods, formulated as:
Projected Unit Credit :

$$^{PUC\,r}(AL)_x = \frac{x-e}{r-e}\ ^{r}(PVFB)_x \tag{14}$$

Entry Age Normal :

$$^{EAN\,r}(AL)_x = \frac{\frac{N_e - N_x}{D_e}}{\frac{N_e - N_r}{D_e}}\ ^{r}(PVFB)_x \tag{15}$$

h. Comparison of methods, conducted by comparing the normal contributions and actuarial liabilities at each participant age to identify the differences between the PUC and EAN methods.

3. RESULTS AND DISCUSSION

The calculation utilizes data on participants of the Ministry of UMKM pension fund. using the example of a participant entering at age 35 ($x = 35$), a retirement age of 58 ($r = 58$), an initial salary of Rp3,089,300 and a pension benefit proportion of 8% of the final salary.

a. Calculating accumulated salary

A participant's accumulated salary can be calculated by summing their annual salaries for the duration of their employment, starting from the first year they became a participant in the pension fund program which is formulated as follows equation (1) and presented by Table 1.

Table 1. Accumulated Salary

Age (x)	MKG	s_x	S_x
35	0	3,089,300.00	37,071,600.00
36	1	3,089,300.00	37,071,600.00
37	2	3,186,600.00	38,239,200.00
38	3	3,186,600.00	38,239,200.00
39	4	3,287,000.00	39,444,000.00
40	5	3,426,000.00	41,112,000.00
41	6	3,533,900.00	42,406,800.00
42	7	3,533,900.00	42,406,800.00
43	8	3,645,200.00	43,742,400.00
44	9	3,645,200.00	43,742,400.00
45	10	3,760,100.00	45,121,200.00
46	11	3,760,100.00	45,121,200.00
47	12	3,878,500.00	46,542,000.00
48	13	3,878,500.00	46,542,000.00
49	14	4,000,600.00	48,007,200.00
50	15	4,000,600.00	48,007,200.00

51	16	4,126,600.00	49,519,200.00
52	17	4,126,600.00	49,519,200.00
53	18	4,256,600.00	51,079,200.00
54	19	4,256,600.00	51,079,200.00
55	20	4,390,700.00	52,688,400.00
56	21	4,390,700.00	52,688,400.00
57	22	4,528,900.00	54,346,800.00
			1,043,737,200.00

b. Calculating the Salary Proportion for Pension Benefits

Using a pension benefit rate (k) of 8% of the salary to determine the pension benefit amount received when the participant reaches retirement age which is formulated as follows equation (2), then:

$$B_r = kS_r$$
$$B_{58} = kS_{58}$$
$$B_{58} = 8\% \ (1.043.737.200{,}00)$$
$$B_{58} = 83.498.976{,}00$$

The calculation results indicate that the accumulated pension benefit for the participant at the retirement age of 58 is Rp.83,498,976. This amount represents the pension benefit derived from the accumulation of the participant's salary over their period of service, applying a benefit factor of 8%.

c. Calculating CIR Parameter Estimates ($\hat{\theta}$, $\hat{k}, \hat{\sigma}$)

Parameter Estimates $\hat{\theta}$, $\hat{k}, \hat{\sigma}$ determined using historical data on SBSN sukuk 2023-2026. The parameter estimates $\hat{\theta}$, $\hat{k}, \hat{\sigma}$ (4), (3), and (5) are presented by Table 2.

Table 2. CIR Parameter Estimation Results

CIR Parameter Estimation Results			
ESTIMATOR	$\hat{k}$	$\hat{\theta}$	$\hat{\sigma}$
RESULT	0.314550325	0.00067565	0.00123

d. Calculating Return on Investment (RoI)

By determining the Return on Investment (RoI) using the CIR model which allows for the stochastic yet realistic modeling of investment yield movements RoI values were obtained for the age range of 35 to 58 years, which is formulated as follows (6) and presented by Table 3.

Table 3. Return on Investment (RoI) Value

x	$R(x)$
35	0.0000
36	0.0213
37	0.0371
38	0.0484

39	0.0563
40	0.0619
41	0.0659
42	0.0686
43	0.0706
44	0.0720
45	0.0729
46	0.0736
47	0.0741
48	0.0741
49	0.0746
50	0.0748
51	0.0749
52	0.0750
53	0.0750
54	0.0751
55	0.0751
56	0.0751
57	0.0751
58	0.0751

e. Calculating Present Value of Future Benefit (PVFB)

The discount factor is determined using the Cox Ingersoll Ross (CIR) model, which yields the Return on Investment (RoI) value at each age. The following is the present value of the pension benefit at age 35 which is formulated as follows (11) :

$$^{58}(PVFB)_{35} = B_{58}\ddot{a}_{58}v_{35\,58-35}P_{35}$$

$$^{58}(PVFB)_{35} = (83.498.976)(\,0{,}4726)(1)(0{,}9116)$$

$$^{58}(PVFB)_{35} = 35.971.992{,}84$$

Table 4. PVFB Participant

$\boldsymbol{x}$	$_{r-x}\boldsymbol{P}_{\boldsymbol{x}}$	$\boldsymbol{v}_{\boldsymbol{x}}$	$^{r}(\boldsymbol{PVFB})_{\boldsymbol{x}}$
35	0.9116	1.0000	35971992.84
36	0.9125	0.9791	35259496.82
37	0.9136	0.9642	34762650.49
38	0.9148	0.9538	34431695.46
39	0.9160	0.9467	34221751.25
40	0.9175	0.9417	34094126.47
41	0.9190	0.9382	34025044.87
42	0.9208	0.9358	34004703.87
43	0.9228	0.9341	34014650.95
44	0.9250	0.9328	34052294.86
45	0.9275	0.9321	34115842.93
46	0.9304	0.9314	34196873.56

47	0.9335	0.9310	34296878.15
48	0.9370	0.9308	34417053.88
49	0.9410	0.9306	34555088.59
50	0.9453	0.9304	34708665.49
51	0.9502	0.9303	34882640.29
52	0.9555	0.9302	35074409.11
53	0.9613	0.9302	35289321.07
54	0.9678	0.9301	35522976.91
55	0.9749	0.9301	35783120.19
56	0.9826	0.9301	36067694.3
57	0.9910	0.9301	36375797.3
58	1.0000	0.9301	36705413.46

f. Calculation of normal contributions

1) PUC Method

Participant contribution at age 35 ($x = 35$) which is formulated as follows (2.12) :

$$^{PUC}\,{}^{58}(NC)_{35} = \frac{{}^{58}(PVFB)_{35}}{58-35} = \frac{35.971.992{,}84}{23} = 1{,}563{,}999$$

2) EAN Method

Participant contribution at age 35 ($x = 35$) which is formulated as follows (2.13) :

$$^{EAN}\,{}^{58}(NC)_{35} = \frac{v^{35-35}\,{}_{35-35}p_{35}\;\;{}^{58}(PVFB)_{35}}{\frac{N_{35}-N_{58}}{D_{35}}}$$

$$= \left(\frac{(1{,}000)^{\frac{l_{35+35-35}}{l_{35}}}}{\frac{N_{35}-N_{58}}{D_{35}}}\right) 35.971.992{,}84$$

$$= \left(\frac{(1{,}000)^{\frac{9{,}795{,}930}{9{,}795{,}930}}}{\frac{20{,}227{,}085-3{,}925{,}366}{9{,}795{,}929}}\right) 35.971.992{,}84$$

$$^{EAN}\,{}^{58}(NC)_{35} = 1.778.407$$

Table 5. Participant Contribution Amounts using the PUC and EAN Methods

x	$^{PUC}r(NC)_x$	$^{EAN}r(NC)_x$
35	1,564,000	1,778,407
36	1,602,704	1,706,827
37	1,655,364	1,657,139
38	1,721,585	1,623,671

39	1,801,145	1,601,702
40	1,894,118	1,587,313
41	2,001,473	1,578,152
42	2,125,294	1,573,224
43	2,267,643	1,570,744
44	2,432,307	1,570,429
45	2,624,296	1,572,040
46	2,849,739	1,574,746
47	3,117,898	1,578,616
48	3,441,705	1,583,705
49	3,839,454	1,589,761
50	4,338,583	1,596,530
51	4,983,234	1,604,383
52	5,845,735	1,613,053
53	7,057,864	1,622,937
54	8,880,744	1,633,530
55	11,927,707	1,645,493
56	18,033,847	1,658,579
57	36,375,797	1,672,747
Σ	**132,382,238**	**37,193,729**

So, the PUC method entails a heavier contribution burden, whereas the EAN method yields stable and constant contributions, thereby facilitating long term pension fund financing planning.

g. Calculation of Actuarial Liabilities

1) PUC Method

Actuarial liability at participant age 35 ($x = 35$), which is formulated as follows (2.14) :

$$^{PUC\ 58}(AL)_{35} = \frac{35-35}{58-35}\ ^{58}(PVFB)_{35}$$

$$^{PUC\ 58}(AL)_{35} = \frac{0}{23}\ 35.971.992{,}84 = 0$$

2) EAN Method

Actuarial liability at participant age 35 ($x = 35$), which is formulated as follows (2.15) :

$$^{EAN\ r}(AL)_x = \frac{\frac{N_e - N_x}{D_e}}{\frac{N_e - N_r}{D_e}}\ ^{r}(PVFB)_x$$

$$^{EAN\ 58}(AL)_{35} = \frac{\frac{N_{35} - N_{35}}{D_{35}}}{\frac{N_{35} - N_{58}}{D_{35}}} 35.971.992{,}84$$

$$^{EAN\ 58}(AL)_{35} = \frac{\frac{20{,}227{,}085-20{,}227{,}085}{9{,}795{,}929}}{\frac{20{,}227{,}085-3{,}925{,}366}{9{,}795{,}929}} 35.971.992{,}84 = 35.971.989{,}88$$

Table 6. Actuarial Liabilities based on the PUC and EAN Methods

x	$^{PUC}r(AL)_x$	$^{EAN}r(AL)_x$
35	-	35,971,990
36	1,533,022	35,259,494
37	3,022,839	34,762,648
38	4,491,091	34,431,693
39	5,951,609	34,221,749
40	7,411,767	34,094,125
41	8,876,099	34,025,043
42	10,349,258	34,004,702
43	11,831,183	34,014,650
44	13,324,811	34,052,294
45	14,832,975	34,115,842
46	16,355,026	34,196,873
47	17,894,023	34,296,877
48	19,453,117	34,417,053
49	21,033,532	34,555,088
50	22,636,086	34,708,665
51	24,266,185	34,882,640
52	25,924,563	35,074,409
53	27,617,730	35,289,321
54	29,345,068	35,522,977
55	31,115,757	35,783,120
56	32,931,373	36,067,694
57	34,794,241	36,375,797
Σ	**384,991,354**	**800,124,743**

Based on the calculation results table, it is evident that the PUC method yields a low actuarial liability at the beginning of the service period, which then increases gradually up to retirement age. In contrast, the EAN method produces a relatively large actuarial liability from the outset and demonstrates a pattern of total accumulation that is significantly higher than that of the PUC method.

h. Comparison of the calculation results from the two methods

Table 7. Comparison of Normal Contribution Calculations

Method	**Comparison of Normal Contribution Calculations**	
PUC	Rp	132.382.238
EAN	Rp	37.193.729

A comparison between the Projected Unit Credit and Entry Age Normal methods regarding normal contributions reveals that, from the participants perspective, the Entry Age Normal method is more advantageous than the Projected Unit Credit method, whereas the Projected Unit Credit method is more advantageous for the sharia pension fund entity.

Table 8. Comparison of Actuarial Liability Calculations

Method	Calculation of Actuarial Liabilities	
PUC	Rp	384.991.354
EAN	Rp	800.124.743

When comparing the Projected Unit Credit and Entry Age Normal methods for actuarial liabilities from the company's perspective, the Projected Unit Credit method is more advantageous for the company, whereas the Entry Age Normal method is more beneficial for sharia pension fund participants.

CONCLUSION

The Entry Age Normal (EAN) method results in a lower total normal contribution Rp.37,193,729 compared to the Projected Unit Credit (PUC) method Rp.132,382,238, making it less burdensome for participants. Conversely, the PUC method yields a lower actuarial liability Rp.384,991,354 compared to EAN Rp.800,124,743, making it more advantageous for the company during the initial period of participation. So, EAN is more suitable from the participants perspective due to lower and more stable contributions, whereas PUC is more suitable from the company's perspective due to the smaller actuarial liability.

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