Simulating pension outcomes using penCalc

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Drivers of pension performance

Context

- Modeling pension outcomes is a critical part of good policy design for a pension system.
- Historically, those running Defined Benefit funds have been significant users of modeling.
- The shift to Defined Contribution pensions puts a much higher premium on understanding the likely outcomes from a given path of contributions and investments.
- Useful for members as well as policy makers.
This paper

- Sets out a new model for pension outcomes called penCalc
- The use of the model is illustrated for India’s National Pension
penCalc

- library in R
- Calculates the expected monthly pension payments
- The package may be installed as follows
  devtools::install_github("renukasane/penCalc").
Structure of the talk

- Drivers of pension performance
- Overview of the model
- Results
Part I

Drivers of pension performance
Drivers of pension performance

- Macroeconomic environment
  - Inflation
  - Bond returns
  - Equity premium

- Annuity prices
We have had very high volatility in inflation.

August 2016, the GOI backed the inflation strategy of the Reserve Bank of India (RBI).

We expect that inflation will have a tight distribution around the mean of 4%.
Over the span of 36 years, equity has given returns of 16%.

The annualised standard deviation is 24.9%
Bond returns

- If we do assume a 4% inflation rate, government bonds at the short end should be around 6%, and on the long end should be around 9%.
- Assume that average nominal return for government bonds of 7%
- Assume a 3% premium on corporate bonds. Hence, a nominal return of 10%.
Annuity prices

The prices for an annuity (Jeevan Akshay VI) which begins at age 60 and pays Rs.1 for life works out to be

- Rs.4087 for a nominal annuity
- Rs.4440 for a nominal annuity with a provision of 50% of the annuity payable to spouse (for life) on death of the annuitant.
- Rs.5589 for an annuity with a provision of 100% of the annuity payable to spouse (for life) on death of annuitant, and return of purchase price on the death of last survivor
Part II

Overview of penCalc
**Inputs**

- Age at entry, age at exit
- Wages
  - Single number, and a growth rate in wages
  - Vector of different values
- Contribution rate
- Inflation
- Investment weights
  - Life cycle weights
  - Constant weights
Inputs (contd)

- **Returns**
  - Mean returns for the three asset classes
  - Standard deviation of returns for the three asset classes

- **Fees and expenses**
  - Monthly fees (% AUM)
  - Annual flat fee (Rs.)

- **Annuities**
  - Percent to be annuitised
  - Price of annuity
Assumptions

Age
Age of entry 25
Age of exit 60

Wages and contributions
Starting wage Rs.25,000 (US$386) per month.
Wage growth (nominal) 8% per anum
Contribution rate 20% of wage

Inflation (mean, sd) (4%, 0)

Investment portfolio
Lifecycle

Returns (nominal)
GOI bonds (mean, sd) (7%, 0)
Corporate bonds (mean, sd) (10%, 0)
Equities (mean, sd) (16%, 25%)

Fees
AUM 0.01% per anum
Flat fee Rs.100 (US$1.5) per anum

Annuities
Percent to be annuitised 40%
Annuity price (for Rs.1 per day nominal annuity) Rs.4,087 (US$63)
Structure of the code

```r
x <- pencalc(
age=list(age.entry=25,
    age.exit=60),
wage=list(25000,
    0.08
    0.2
    initial.amount=0),
inflation=list(c(0.04,0)
    ,real=TRUE),
inv.weights=list("lc"),
returns=list(data.frame(mean=c(0.07, 0.10, 0.16),
    sd=c(0, 0, 0.25)),
    c(monthly.fees.expenses=0.01, 100)),
annuity=list(perc.annuitised=0.4,
    value=4087))
```
The working of the model

- Starting wage and the yearly growth rate in wages are used to generate a vector of wages for the years the subscriber is expected to be in the system.
- The wages are expected to stay the same in each month of the year.
- The default number of years is 60-25+1, that is 36 years.
- The contribution rate is then used on this vector of wages to arrive at the rupee value of contributions.
- The mean and standard deviations of the underlying instruments (bonds and equity) are used to simulate returns on the investment each year as a draw from a normal distribution.
- The returns are annualized figures, and are converted to monthly returns.
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- The returns are annualized figures, and are converted to monthly returns.
The working of the model (contd)

- The investment weights and returns are used to arrive at a portfolio return.
- The monthly fees and expenses are deducted from the portfolio returns.
- The contributions and returns are accumulated over each year in the system, and give us the total expected accumulation in the pension account.
- If the user has entered the “real” option, then the rate of inflation is subtracted from the wages, and returns assumptions.
- This simulation is done 1,000 times, and thus generates a distribution of the expected accumulated amounts in the NPS account.
- The amount to be annuitized is subtracted from this accumulation and used to arrive at the monthly expected pension using the annuity price.
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Outcomes

- In hand accumulation
- Monthly pension
- Replacement rate
Part III

Results
GOI bonds portfolio: 85% bonds, 15% equity

library(penCalc)
weightmatrix <- data.frame(goi_bonds=rep(0.85, 36), corp_bonds=rep(0,36),
                           equity=rep(0.15,36))

set.seed(111)
# 40% annuity
x <- pencalc(inflation=list(c(0.04,0)
                             ,real=TRUE),
             inv.weights=list(weightmatrix))

# 100% annuity
y <- pencalc(inflation=list(c(0.04,0)
                             ,real=TRUE),
               inv.weights=list(weightmatrix),
               annuity=list(perc.annuitised=1,
                             value=4087))

y
## Results: GOI bonds portfolio

<table>
<thead>
<tr>
<th></th>
<th>40%</th>
<th></th>
<th>100%</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>In hand accumulation (In million)</td>
<td>4.70</td>
<td>0.17</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Monthly Pension (In Rs.)</td>
<td>23,297</td>
<td>828</td>
<td>58,242</td>
<td>2,072</td>
</tr>
<tr>
<td>Replacement Rate (In%)</td>
<td>23.60</td>
<td>0.80</td>
<td>59.00</td>
<td>2.10</td>
</tr>
</tbody>
</table>
Distribution of replacement rates
library(penCalc)
set.seed(111)
# 40% annuity
set.seed(111)
x <- pencalc(inflation=list(c(0.04,0)
                      ,real=TRUE),
                      inv.weights=list("lc"))
x

# 100% annuity
set.seed(111)
y <- pencalc(inflation=list(c(0.04,0)
                      ,real=TRUE),
                      inv.weights=list("lc"),
                      annuity=list(perc.annuitised=1,
                                    value=4087))
y
## Results: Life cycle weights

<table>
<thead>
<tr>
<th></th>
<th>40%</th>
<th>SD</th>
<th>100%</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>In hand accumulation (In Rs.million)</td>
<td>7.41</td>
<td>0.75</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Monthly Pension (In Rs.)</td>
<td>36744.3</td>
<td>3702.4</td>
<td>92034.2</td>
<td>9520.09</td>
</tr>
<tr>
<td>Replacement Rate (In%)</td>
<td>37.20</td>
<td>3.80</td>
<td>93.10</td>
<td>9.40</td>
</tr>
</tbody>
</table>
Results: Lower equity returns

1. We assume a 12% rate of return and a 20% standard deviation. This amounts to an equity premium of 5%.

2. We assume a 10% rate of return and a 18% standard deviation. This amounts to an equity premium of 3%.

<table>
<thead>
<tr>
<th></th>
<th>12% return</th>
<th>10% return</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>In hand accumulation (In Rs. million)</td>
<td>6.64</td>
<td>0.68</td>
</tr>
<tr>
<td>Monthly Pension (In Rs.)</td>
<td>32,952.0</td>
<td>3,398.3</td>
</tr>
<tr>
<td>Replacement Rate (In%)</td>
<td>33.40</td>
<td>3.40</td>
</tr>
</tbody>
</table>
### Results: Different annuity prices

<table>
<thead>
<tr>
<th></th>
<th>Nominal</th>
<th>50 % spouse</th>
<th>100 % spouse</th>
<th>WB price</th>
</tr>
</thead>
<tbody>
<tr>
<td>In hand accumulation (In Rs. million)</td>
<td>7.41</td>
<td>7.41</td>
<td>7.41</td>
<td>7.41</td>
</tr>
<tr>
<td>Accumulation std. dev</td>
<td>(0.75)</td>
<td>(0.75)</td>
<td>(0.75)</td>
<td>(0.75)</td>
</tr>
<tr>
<td>Monthly Pension (In Rs.)</td>
<td>36,744.3</td>
<td>34,130.4</td>
<td>26,869.5</td>
<td>22,524.9</td>
</tr>
<tr>
<td>Pension SD</td>
<td>(3702.4)</td>
<td>(3439.1)</td>
<td>(2,707.4)</td>
<td>(2269.7)</td>
</tr>
<tr>
<td>Replacement Rate (In %)</td>
<td>37.2</td>
<td>34.6</td>
<td>27.2</td>
<td>22.8</td>
</tr>
<tr>
<td>RR SD</td>
<td>(3.8)</td>
<td>(3.5)</td>
<td>(2.7)</td>
<td>(2.3)</td>
</tr>
</tbody>
</table>
library(penCalc)
wage = round(rnorm(36, 3000, 100),0)
set.seed(111)
x <- pencalc(wage=list(wage
    ,0
    ,1
    ,initial.amount=0),
    inflation=list(c(0.04,0)
    ,real=TRUE))
x

#100 %

set.seed(111)
y <- pencalc(wage=list(wage
    ,0
    ,1
    ,initial.amount=0),
    inflation=list(c(0.04,0)
    ,real=TRUE),
    annuity=list(perc.annuitised=1, value=4087))
y
## Results: Varying contribution rates

<table>
<thead>
<tr>
<th></th>
<th>40%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>In hand accumulation (in Rs. million)</td>
<td>2.71</td>
<td>0.00</td>
</tr>
<tr>
<td>Monthly Pension (in Rs.)</td>
<td>13,454.1</td>
<td>33,635.2</td>
</tr>
<tr>
<td>Mean</td>
<td>1,698.3</td>
<td>4,245.9</td>
</tr>
<tr>
<td>SD</td>
<td>0.34</td>
<td>0.00</td>
</tr>
</tbody>
</table>
Part IV

Way forward
Future work

- A GUI based front-end
- Build more functionalities. For example:
  - Possibility of premature withdrawals
  - Asset correlations
- Impact of international diversification for pension funds (such as the EPFO).
Thank you