Business Planning Under Uncertainty

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Business Planning Under Uncertainty

A Bayesian Approach

21 April 2017

Institute
and Faculty
of Actuaries

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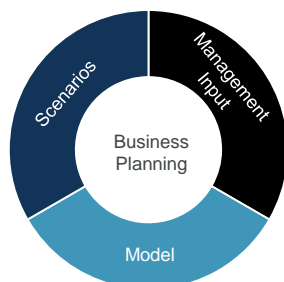feifei.zhang@kpmg.com

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Agenda

- Insurance company business planning
- Our model – a Bayesian approach
- Genetic algorithm
- Observations and conclusions

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Insurance Company Business Planning

Planning Period :
2017-2020
Business Unit :
Life Insurance
BE Scenario :
EV Basis

	YE 2016	YE 2017	YE 2018	YE 2019	YE 2020
Profit					
ROEC					
Cash					
Expense					
EVNBV					

Scenarios: economic, regulatory, market
Management Input: sales, investment, capital

Model – that's what we are talking about today

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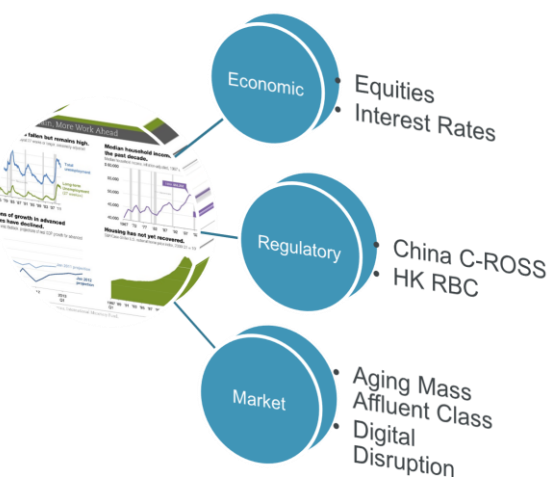
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Scenarios

- Equities
- Interest Rates

- China C-ROSS
- HK RBC

- Aging Mass Affluent Class
- Digital Disruption

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Our Model – a Bayesian Approach

- Model Objectives (upside risk)

Optimal new business <u>sales volume</u> to maximise the

"<u>defined total profit</u>"* projected <u>over N years</u>

- Model Constraints (downside risk)

Solvency capital ratio (capital risk appetite)

Can be extended to other financial management decision-making process such as ALM/SAA

* Average profit before tax and before solvency consideration

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Our Model – a Bayesian Approach

- Economic cycles: boom, recession, and two transitions
        Controlling equity and rates behaviours
- A Markov Regime Switching (MRS) process
        Hamilton (1990,1991)
        Hardy (2001)
- Multivariate optimisation with constraints
        Hamilton (1990) – Quasi Log-likelihood (QL)
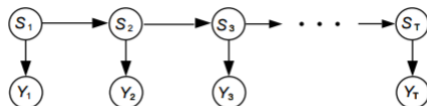   Franses • van Dijk (2000) – Expectation Maximisation (EM)
        Genetic Algorithm (GA)

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Our Model – Hidden Markov Model (HMM)
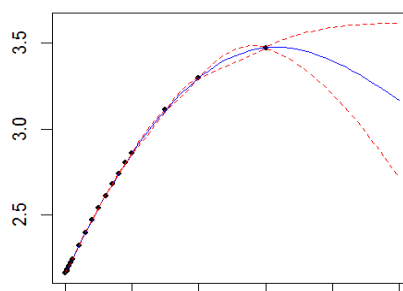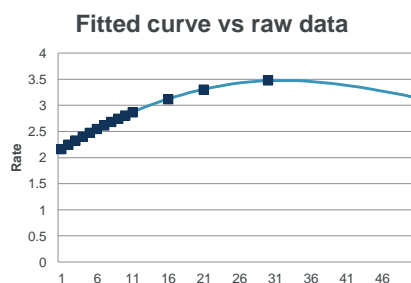
- A Markov process with unobserved (hidden) states.

- 4 state HMM
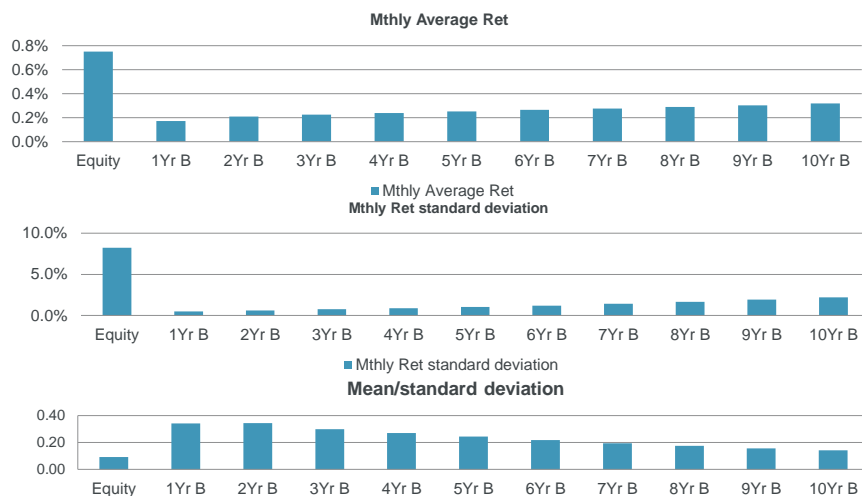- HMM will reach a stationary distribution for each states

Our Model – Assets

- Equity total return index
- Bond portfolio (1-10 year zero coupon bonds) total return index
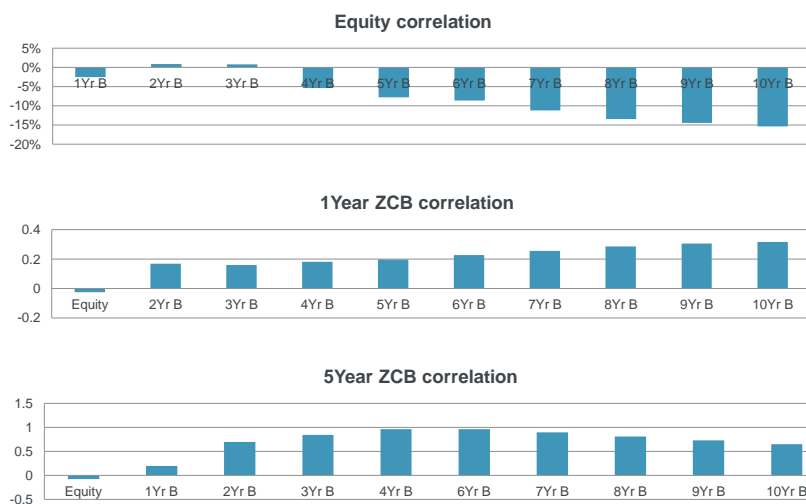- Smoothed monthly yield curve (Gaussian process)

Fitted curve vs raw data

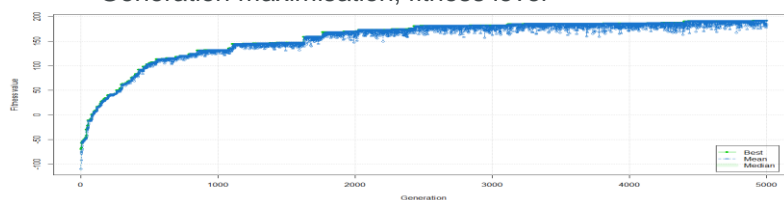# Equity & ZCB Bond returns

Equity & ZCB Bond return correlations

Genetic Algorithm

- Evolution: mutation and alteration

  Candidate individuals, genotype, encoding

- Fittest to survive

  Iteration of generations, selection, genome modification

- Target: Equity total return index

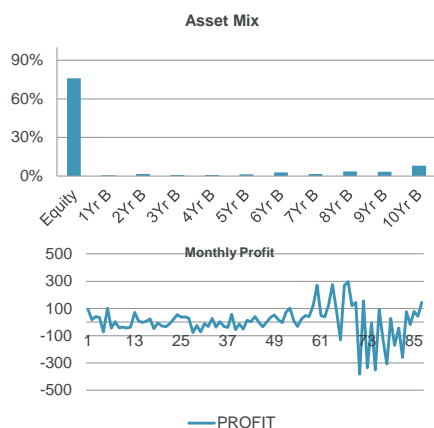 Generation maximisation, fitness level

Our Model – Liabilities

- Endowment, Unit Linked and With Profit
- Single premium 10 year maturity
- PVFP pricing
- Ignoring mortality, lapse and expense
- Deterministic discounting

First Target – Optimise PVFP

Asset Mix

Monthly Profit

- This target has not considered the fluctuation of profit over different policy year
- Equity return is highest so it is not surprising to see the optimal asset mix is equity
- Smoothed profit preferred

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Second Target – Optimise PCFP with Loss Penalisation

Asset Mix

Monthly Profit

- Exclude large loss in any single month
- Used to optimise the Unit Linked and With Profit product asset mix

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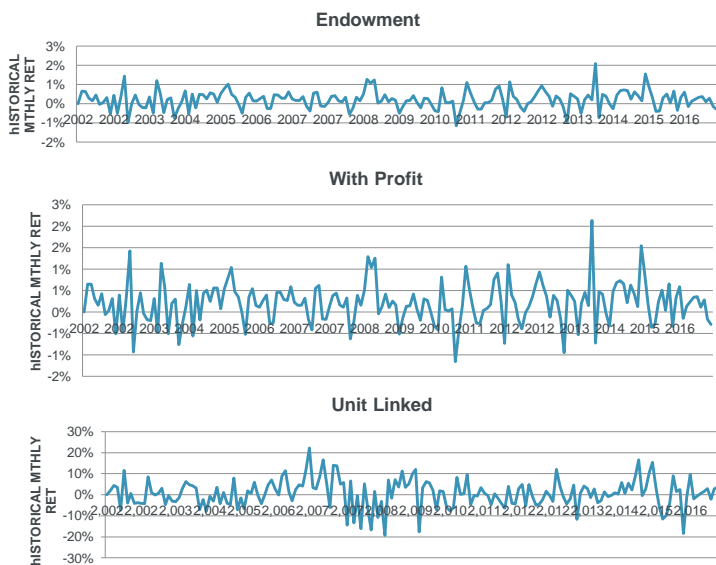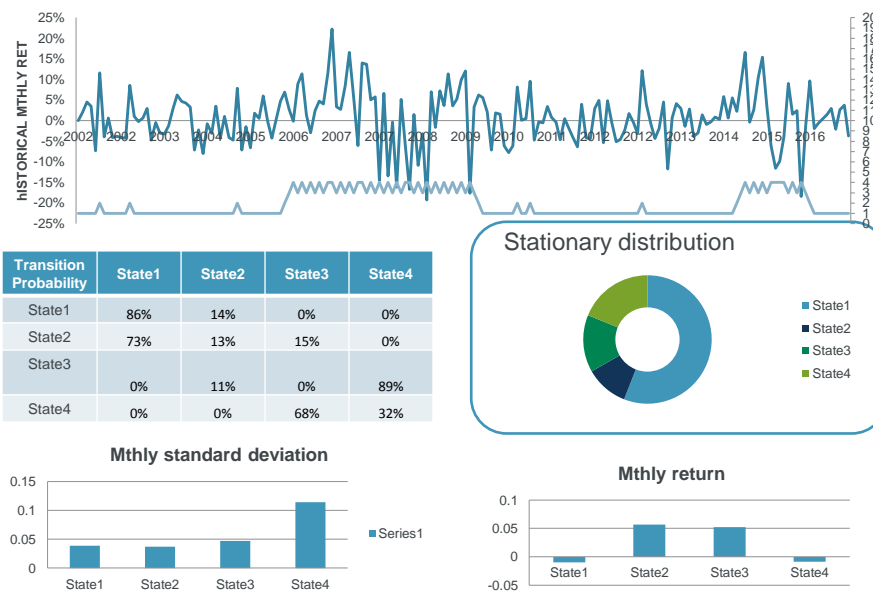# Optimal Asset Mix

Endowment Asset Mix

With Profit Asset Mix

Unit Linked Asset Mix

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Historical Returns

Endowment

With Profit

Unit Linked

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4 States Hidden Markov Model – Unit Linked

Transition Probability	State1	State2	State3	State4
State1	86%	14%	0%	0%
State2	73%	13%	15%	0%
State3	0%	11%	0%	89%
State4	0%	0%	68%	32%

Stationary distribution

State1, State2, State3, State4

Mthly standard deviation

Series1

Mthly return

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4 States Hidden Markov Model – Endowment

Transition Probability	State1	State2	State3	State4
State1	60%	40%	0%	0%
State2	16%	60%	24%	0%
State3	21%	0%	0%	79%
State4	12%	88%	0%	0%

Stationary distribution

State1, State2, State3, State4

Mthly standard deviation

Mthly return

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4 States Hidden Markov Model – With Profit

Transition Probability	State1	State2	State3	State4
State1	59%	41%	0%	0%
State2	12%	62%	26%	0%
State3	33%	0%	0%	67%
State4	11%	89%	0%	0%

Stationary distribution

- State1
- State2
- State3
- State4

Mthly Standard deviation

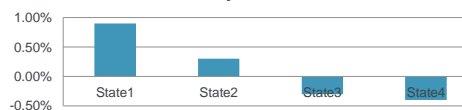Mthly returns

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Gaussian Copula to correlate the simulated monthly returns
Historical monthly return correlation vs simulated correlation

Historical data	Unit Linked	With Profit	Endowment
Unit Linked	100%	29%	32%
With Profit	29%	100%	100%
Endowment	32%	100%	100%

Simulation	Unit Linked	With Profit	Endowment
Unit Linked	100%	24%	27%
With Profit	24%	100%	98%
Endowment	27%	98%	100%

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Profit & Cash Flow by Products

ED Profit

ED Cash flow

WP Profit

WP Cash Flow

UL Profit

UL Cash Flow

Assume 5 year equal new business

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Experiment 1: Optimise Product Mix to Smooth Profits

Average Profit

Equal_weight[1] Smoothing[2]

UL WP ED

By penalising the variance of average profit over year, we get the smoothed annual profit result with similar average profit

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Profit and EV results[1]

Equal weighted business mix

	YE2017	YE2018	YE2019	YE2020	YE2021
Profit	129	144	157	173	191
EVNBV	427	427	427	427	427
EV in force	349	311	273	228	177
Cash Flow	1,066	1,130	1,181	1,253	1,327

Product Type	Product Mix
UL	33%
WP	33%
ED	33%

Weights optimised to smooth annual profit

	YE2017	YE2018	YE2019	YE2020	YE2021
Profit	61	83	104	127	150
EVNBV	460	460	460	460	460
EV in force	533	476	416	347	271
Cash Flow	1,136	1,242	1,320	1,437	1,558

Product Type	Product Mix
UL	73%
WP	0%
ED	27%

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Experiment 2: Optimise Product Mix to first 5 year profits

Profit

Average Profit

Max First 5 Year Profit

Equal_weight[1]   Max First 5 Year[2]

UL
WP
ED

By maximizing the first 5 year profit, the weight changed to WP dominant as its profit emerge more in the beginning 5 year

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Profit and EV results[2]

Equal weighted business mix

	YE2017	YE2018	YE2019	YE2020	YE2021
Profit	129	144	157	173	191
EVNBV	427	427	427	427	427
EV in force	349	311	273	228	177
Cash Flow	1,066	1,130	1,181	1,253	1,327

Product Type	Product Mix
UL	33%
WP	33%
ED	33%

Weights optimised to max first 5 year annual profit

	YE2017	YE2018	YE2019	YE2020	YE2021
Profit	202	210	216	226	236
EVNBV	377	377	377	377	377
EV in force	148	128	110	90	68
Cash Flow	818	849	879	913	948

Product Type	Product Mix
UL	0%
WP	99%
ED	1%

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Experiment 3: Optimise Product Mix to 1_IN_200 Annual Profits

Max 1_IN_200 weight

Annual 1-IN-200 Profit

Legend: Equal_weight[1], Max 1_IN_200 Profit[2]

Pie legend: UL, WP, ED

By maximizing annual 1_IN_200 profit, the weight changed to UL dominant as its profit is most stable

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Profit and EV results[3]

Equal weighted business mix

	YE2017	YE2018	YE2019	YE2020	YE2021
Profit	129	144	157	173	191
EVNBV	427	427	427	427	427
EV in force	349	311	273	228	177
Cash Flow	1,066	1,130	1,181	1,253	1,327

Product Type	Product Mix
UL	33%
WP	33%
ED	33%

Weights optimised to max 1_IN_200 annual profit

	YE2017	YE2018	YE2019	YE2020	YE2021
Profit	36	61	86	111	136
EVNBV	465	465	465	465	465
EV in force	600	535	464	386	300
Cash Flow	1,058	1,186	1,281	1,422	1,567

Product Type	Product Mix
UL	94%
WP	6%
ED	0%

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Summary

1. Unit Linked
   - profit from the asset management charge
   - policyholders take the investment risk
   - optimal strategy: more aggressive SAA
   - cash flow more volatile although profits are smoothed
2. With Profit and Endowment
   - investment risk shared between policyholders and shareholders
   - optimal strategy: less aggressive SAA
   - profits less smoothed

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Future improvements

1. Liability model to include dynamic lapse rates, correlated to movement of yield curve
2. Include regular premium products
3. Include expense assumption
4. Develop the solvency capital projection
5. More data (higher frequency)
6. Multi-dimensional optimisation (proper ALM – adjusting sales and SAA at the same time): more powerful PC!
7. More asset classes, e.g. credit

Questions Comments