2nd 4-University Rotational FinTech Conference
Seoul 12th April 2018

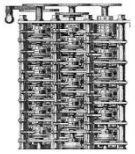
Intelligent Robo Investment Advice

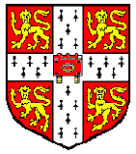
M A H Dempster

Centre for Financial Research, Statistical Laboratory, University of Cambridge
&
Cambridge Systems Associates

mahd2@cam.ac.uk www.cfr.statslab.cam.ac.uk

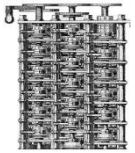
Co-workers: Dwayne Kloppers, Elena Medova, Igor Osmolovskiy & Philipp Ustinov





Outline

- Introduction and Background
- Current Industry Standard Advice
- Individual Goal Driven Financial Planning Advice
- Optimal Goal Driven versus Industry Standard Advice
- Conclusion

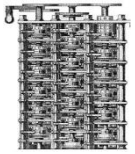


[The] assumption that the future will be like the past, at any rate in the economic sphere, is perhaps more questionable now than for decades. All around the world we stand on the cusp of a dramatic shift in the structure of our populations, the aging of our people

Goodhart and Erfuth (2015)

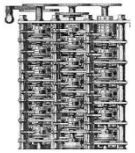
- Long term demographics, uncertain recovery from the recent crisis and the inexorable rise of government welfare costs have led to the global dramatic shift in retirement provision from governments and companies to individuals by means of defined contribution pension schemes and tax advantaged individual retirement savings

- This shift has been accompanied by steadily increasing government regulations of the insurance and investment management industries – particularly regarding advice given to individuals at all levels of society



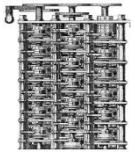
Individual Investment Products and Advice

- Financial products and planning for the benefit of individual investors are currently based internationally on a wide variety of approaches ranging from simple heuristics to sophisticated joint stochastic optimization of asset allocation, allocation to different savings vehicles and setting savings and withdrawal rates
- Rapidly developing expansion of affordable massive computing power implies the trend from current basic robo advice to more sophisticated approaches and products will accelerate



" The theories (utility theory and its behavioral alternatives) assume that individuals *correctly anticipate their reaction to possible outcomes and incorporate valid emotional prediction into their investment decisions*. In fact, people are poor forecasters of their future emotions and future tastes – they need help in this task – and I believe that one of the responsibilities of financial advisors should be to provide that help"

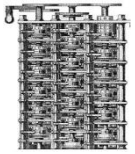
Daniel Kahneman



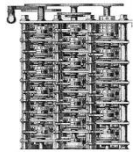
Framing the Financial Planning Problem?

"We do not prosper by income or happiness alone"
Samuel Brittan

"Is wealth the long-term spending that our portfolio can sustain ? This definition is close to the truth, but it ignores purchasing power. Is wealth, then, the inflation-indexed real income that our assets could sustain over time? For most investors, this is probably the most useful definition of wealth."
Robert Arnott

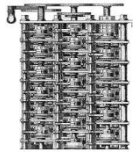


Current Industry Standard Advice



Individual Financial Advice

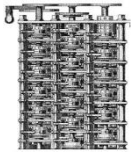
- Softer advice issues
  - Do you have a will?
  - Helping someone through the administration of opening investment accounts
  - Assistance with savings/adjusting a budget
  - Resolving such issues has a real significant value
  - The man on the street has only a limited chance of being able to gauge quality of the service he or she is receiving



Financial Planning for Individual Households

- Financial planners have traditionally resisted the academic solutions based on theoretical models
  - Asset allocation puzzle of Canner *et al.* Campbell (2002)

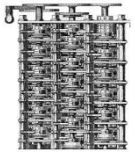
- Common practice is based on the qualitative assessment of risk attitude by financial advisers
  - Rule of thumb: equity fraction of one's portfolio equals 100 – one's age (life-staged funds) John Bogle, Vanguard Group
  - "The myth of risk attitudes" Daniel Kahneman (*JPM*, Fall 2009)



New Product Institutional Risk Management

Requires

- **Understanding the social security system and pension regulations**
- **Modelling aggregated liabilities of pension schemes and insurance funds**
  - **e.g. minimum guaranteed fund returns, insurance claims, variable annuities, corporate pension payments, etc**
- **Modelling of fundamental economic factors and market returns in economic scenario generators**
  - **e.g. inflation and wages, yield curves, asset returns, etc**
- **Actuarial modelling of mortality and longevity risks, benefit payments to workers, etc**
- **Corporate decisions regarding funding ratios**
- **Optimization of contribution rates for employers and employees**



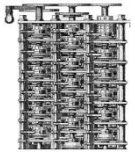
US GAO Report on 401k Plans (2014)

- Managed accounts are:

investment services under which providers make investment decisions for specific participants to allocate their retirement savings among a mix of assets they have determined to be appropriate for the participant based on their personal information

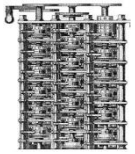
- Managed accounts attempt to "customize" or "personalize" an investor's strategy

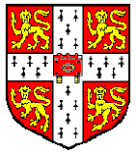
- Although these strategies include some tailoring to individual needs, the actual underlying strategy is *not optimised* to these needs. In most cases, the investment strategy is developed using conventional mean-variance optimisation or without any formal optimisation (*op cit.,* pp. 17-18)



What is Algorithmic Advice?

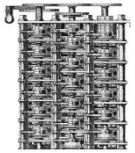
- Objectively determined advice involving a rules based part
- "Objective function" to be "optimized"
- Quality – explicit problem formulation, how appropriate, how rigorously solved/optimised – varies massively across the advisory industry
- Features range across
  - An independent financial advisor (IFA) talking to individual client
  - Automated 'managed account' often for defined contribution pension plans
  - One-size-fits-all product packaging used for some pension funds
- Algorithmic advice as currently embodied by basic robo advice is the component of individual financial advice least understood by clients and arguably the industry itself
- Yet its quality likely makes the biggest difference to individual outcomes





Why is Algorithmic Advice of Particular Interest to Providers Currently?

- Financial service providers (FSPs) sell 'advice' – this is one of their primary reasons for being
- Ultimately it is the value proposition that enables them to charge clients and extract value
- For long run survival of an advisory firm the longer term value of their advice should be 'sound'

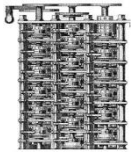


Current Relevance of Algorithmic Advice

- This is particularly pertinent as consumers and regulators become
  - more cost sensitive
  - more value sensitive
  - better informed and better able to compare/share products and experiences on social media
  - more accustomed to real time solutions
  - more comfortable with automation and online solutions

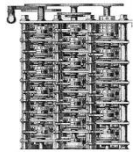
and in light of

- the rapid rise of the robo advisor
- the rapid rise of managed accounts and DC schemes



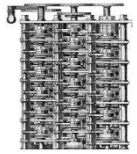
Purpose of Our Recent Research

- With this backdrop we set about surveying the approaches currently used globally in industry
- A sort of "literature review" of the financial advisory industry
- We set about showing how vastly different the approaches being used are and measuring the value that can be unlocked with proper modelling and optimization
- We find this value add to be **large** Dempster et al. (2016)

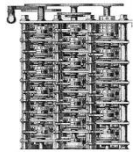


Teaser – How much better is the optimal goal driven strategy embodied in intelligent robo advice than?

The best life staged/target date strategy	9%
Ultra aggressive mean variance optimal	10%
Static living annuity draw down	5%



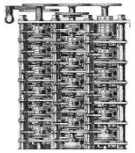
Individual Goal Driven Financial Planning Advice



Financial Planning

- *"Is Personal Finance an exact science? An immediate flat no. … It is a domain full of ordinary common sense. Alas, common sense is not the same thing as good sense. Good sense in these esoteric puzzles is hard to come by."*

  Paul Samuelson
- Is reconciliation of theory and practice possible?
- In the search for 'good sense' we can apply a modelling methodology which comes from Operations Research – decision making in the face of uncertainty
- In financial planning the principal ideas can be brought together from behavioural and classical finance using stochastic optimization theory and techniques



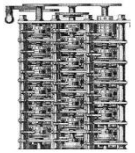
Individual Asset Liability Management: *i*ALM

- The ***i*ALM system** is a **decision support tool** based on the **theory of stochastic optimization** which may be termed an **intelligent robo advisor**

- ***i*ALM generates life-cycle recommendations** for managing wealth and other critical decisions selected by the user over his/her life span such as level of saving or spending at retirement, borrowing, sending children to private schools, buying real estate, and so on

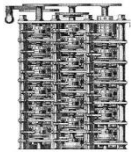
- It allows **interactive re-solving** to obtain long-term financial plans with modified data inputs in order to **compare the consequences of the changes** in individual preference

- Principal ideas are brought together from **behavioural and classical finance** and **decision theory**



Modelling Life Style

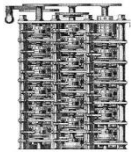
- Ideally construction of a problem suitable for general households from different age and wealth groups which must reflect individual circumstances
  - Planning horizon for each problem depends on the age of individuals
  - Major impacts of uncertain events: Long Term Care and Death
  - Medical expenses depend on the state of health and insurance
- Forecasting of earned income
- Client's defined specific goals and spending on these goals within a range of desirable, acceptable and minimum levels



Framing the Problem

- **Broad Framing:** overall objective is to provide **'sustainable spending'** over a household's lifetime in terms of desired multiple life goals specified by preferences on goal choice and their priorities

- **Narrow Framing:** maximization of goal consumption
  - each single **goal utility function** is defined with respect to the **3 reference points** chosen by the household in specifying its individual consumption preferences
  - a highly popular goal example in the US and UK – private education of a child



Overall Objective

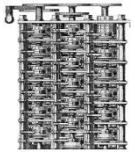
- The objective is to maximize the expected present value (over all scenarios) of life time consumption, i.e. spending on all selected goals

$$\mathbb{E}\left[\sum_{t=1}^{T}\mathbf{1}_{\{\text{any alive},t\}}\mathbf{u}_t\right]$$

where $\mathbf{u}_t = \sum_{g\in G}\mathbf{u}_{g,t} - \frac{1}{\boldsymbol{\varphi}_t}\left(\pi^{xs}\mathbf{z}_t^{xs} + \pi^{\tau i}\mathbf{I}_t^{\tau}\right)$

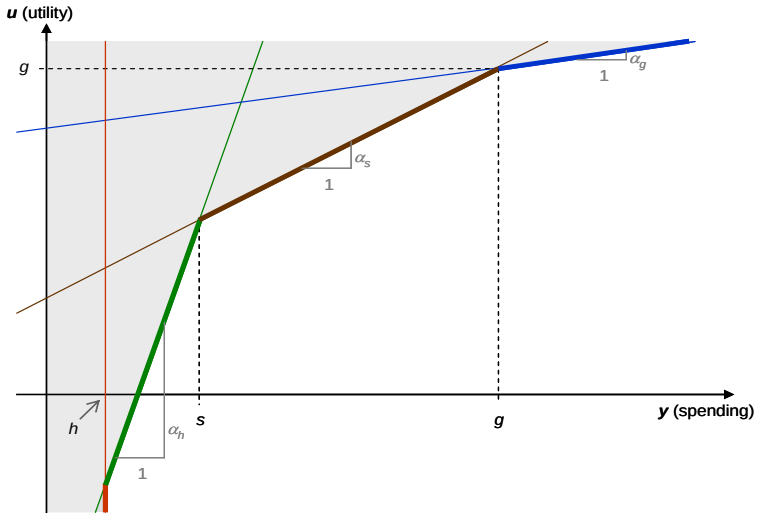
Here $\mathbf{z}_t^{xs}$ is excess borrowing, $\mathbf{I}_t^{\tau}$ is total tax payment and $\boldsymbol{\varphi}_t$ is the inflation index at t

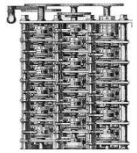
- Here consumption refers to all "elective" spending on chosen goals



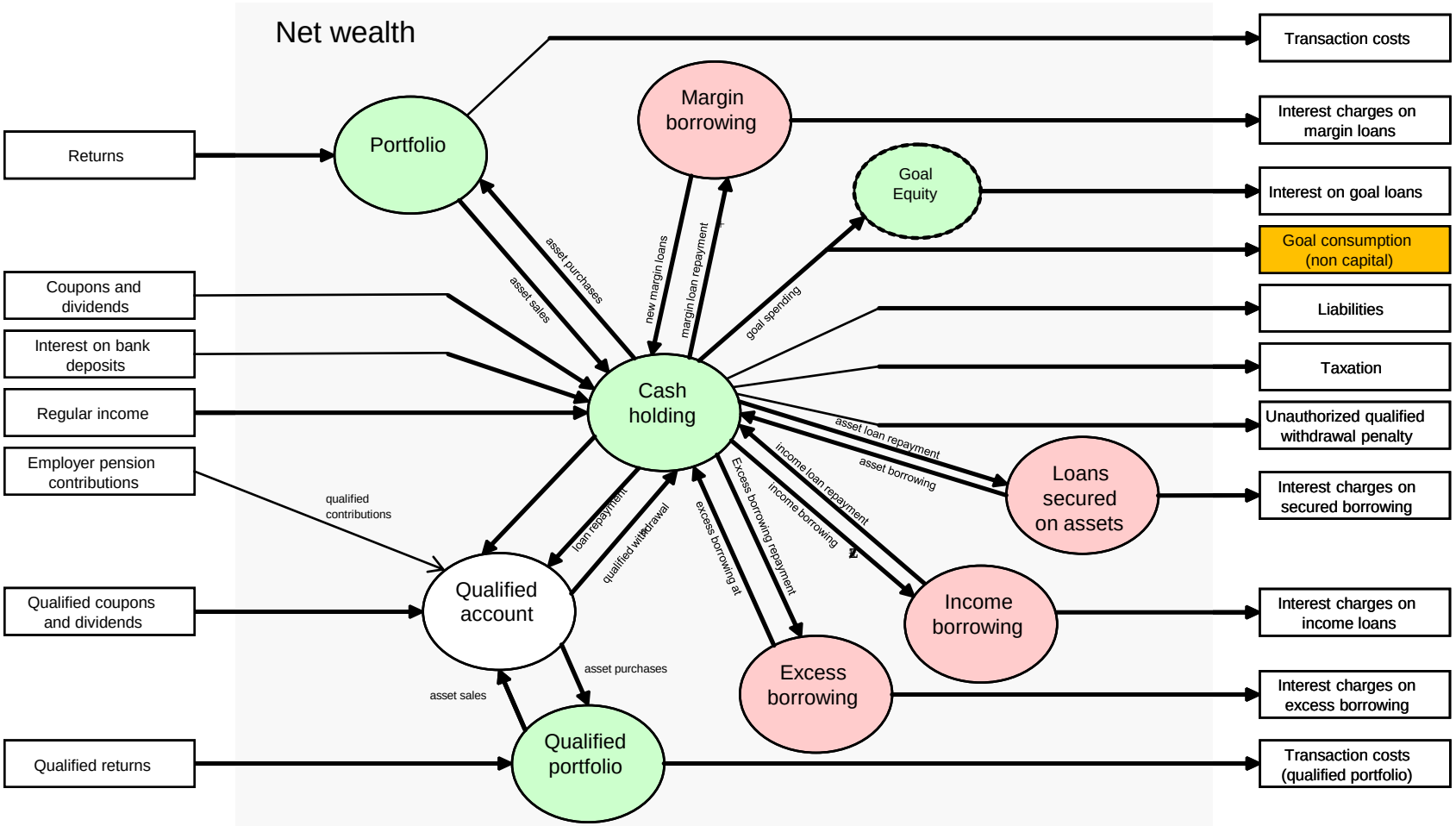
Individual Goal Utility

- Individual goal utility function is given by **three** reference points
- For each single goal the level of spending ***y*** is in the range between acceptable (s) and desirable (g) subject to existing and foreseen liabilities, i.e. minimum (h) spending. These values specify the shape of the utility function for **each** goal
- Objective is to maximize goal spending with piecewise linear utility functions for goal spending with priorities





Cash Flow Network

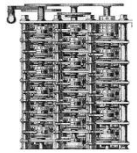


Key Modelling Features

- **Portfolio return and risk** are driven by **desirable consumption** subject to existing and future liabilities

- **Risk management** of portfolio by
  - Constraining the **portfolio drawdown in each scenario**
  - Constraining the **proportion of assets** in the portfolio

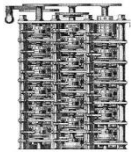
- Length of each individual scenario represents a possible duration of life, i.e. we solve a problem with a **random time horizon**



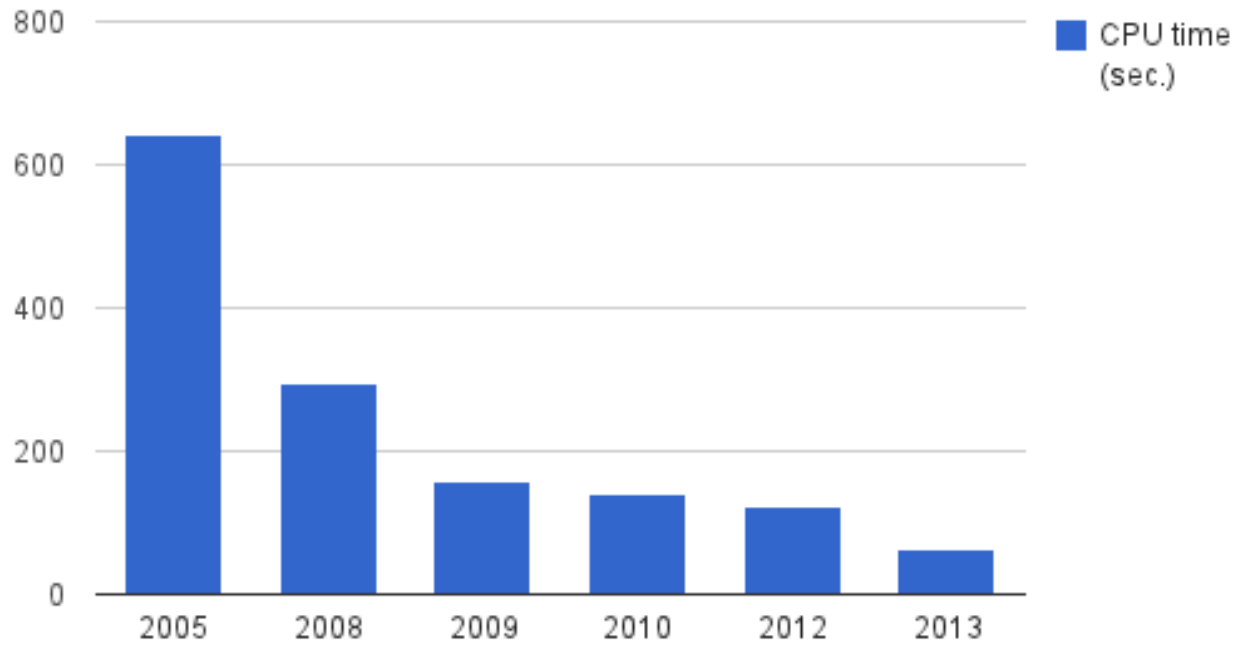
Wealth Generation Through Optimum Resource Allocation

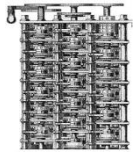
- *i*ALM objectives are achieved through **optimum resource allocation** over a network of cashflows
  - **cash flows** of liabilities
  - **cash flows** of different incomes and portfolio returns
  - **income from portfolio returns provides optimal consumption**

➢ **An interactive process for analysing retirement and saving alternatives**



Technology & HPC Techniques Impact





Getting an Overview

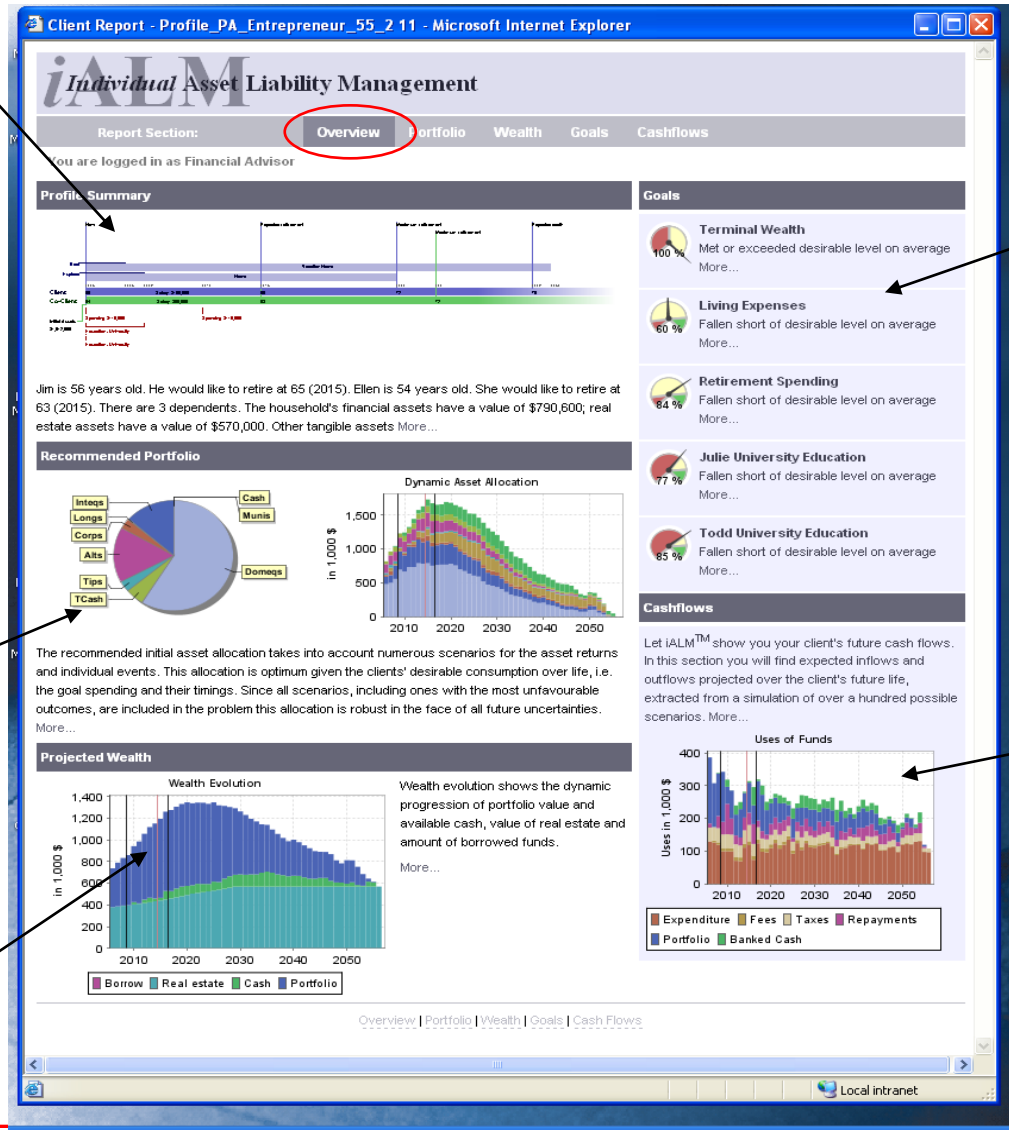
Visual Summary of Profile

Goals

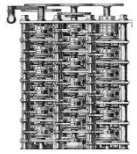
Portfolio

Cash Flows

Wealth



Optimal Goal Driven versus Industry Standard Advice

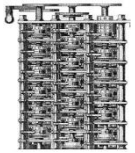


How *i*ALM Differs from Industry Practice

- Goal based investing
  - Optimization relative to need for an income
  - Globally industry talks goal based but mostly still uses outdated goal agnostic pure return approaches (e.g. MVO or modern portfolio theory, 1952, or risk parity as embodied in currently available robo advisors)

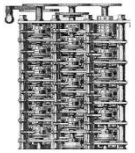
- Individualised
  - Solves your specific financial problem not that of some average person

- Utility maximization
  - Not limited to considering single values of a distribution (e.g. VaR, shortfall probabilities)
    - Single value approaches always result in 'corners' in advice – i.e. give illogical results in some of the given support
  - Recognises that very low incomes are highly unattractive (i.e. gives depth of shortfall)
    - Although not perfect utilities are widely used and accepted as a pragmatic example of normative theory



*i*ALM's Approach is Holistic

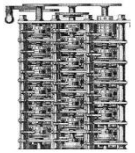
- Optimization is possible jointly across
  - tax
  - allocation to savings vehicles (e.g. tax free account, pensions, etc)
  - consumption (rate of saving and post retirement rate of income draw down each month)
  - annuitisation decisions
  - what to invest in post retirement
- At retirement annuitization is not assumed
- Not aware of other publically available research optimizing these decisions jointly with recourse with no return independence assumed
- Simultaneous linear equation constraints in over 2 million variables



Advantages of *i*ALM for This Comparison

- *i*ALM incorporates "all the sophistication one can throw at the life cycle consumption investment problem currently"

- Good test bed
  - Can disable functionality and work backwards to other simpler market approaches
  - World leading optimisation potency on this style of problem
  - Wide applicability
    - Universal nature of the theoretical economic framework
    - Speed/efficiency of the solvers
    - IFA tool, managed accounts engine or research tool



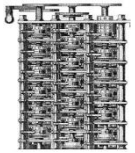
Household Profiles

Profile A

This young individual is 30 years old, has no savings, earns £60k gross (equal to about 45k after tax) and has spending goals for (minimum, acceptable and desirable) sterling amounts corresponding to (30k, 40k, 50k) pre-retirement and to (7.5k, 40k, 70k) upon planned retirement at 65. The £7.5k per annum minimum amount post retirement represents the current UK subsistence level

Profile B

This individual is 65 years old, has just retired and therefore does not earn a salary. He has £600k in initial savings, and his post-retirement spending goals for (minimum, acceptable and desirable) amounts correspond to (7.5k, 40k, 70k)

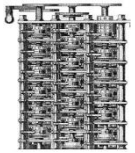


Investment Strategies Compared

- Our experiments decompose more granularly the value added by optimizing the optimal expected value of lifetime utility with a fully dynamic strategy

- In moving from the fixed strategies to the fully optimised strategies we are combining a number of incremental strategy value adds:
  1. The effect of switching from a static fixed MVO strategy to a liability/utility relative fixed strategy optimization
  2. The effect of dynamism (allowing a strategy that varies across time)
  3. The effect of fully path dependent dynamism (allowing a different strategy depending on the known path up the point of the decision)

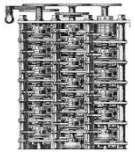
- Each step adds complexity to the problem to be solved and all current solutions used in practice ignore one or more of these features in order to make the problem easier to solve



Initial Gap Comparison Measure

- Initial gap
  - Extra upfront investment required for an inferior strategy to equal optimal strategy utility
  - Really simple for the man in the street to understand
  - Independent of utility scale with common random time horizon for all utility based strategies

- We also use more sophisticated techniques from the literature



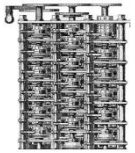
Gamma Equivalence Measure

- Gamma
  - Percentage increase in certainty equivalent income in moving between strategies
  - This is ‘with scale’, ‘with interpretation’ way to evaluate things within a utility framework
  - Invented as a measure of the value of financial advice by MorningStar

  (“Alpha, Beta and now ...Gamma” Blanchett & Kaplan, 2013)

- Gamma equivalent alpha
  - The alpha needed to get the inefficient *allocation/strategy* to the same ‘goodness’ level in terms of utility as the better strategy

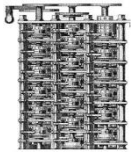
  Dempster *et al.* (2016)



Goal Agnostic (Markowitz) Strategy versus Life Cycle Goal Achievement

- The full dynamic *i*ALM strategy is **10%** more efficient than aggressive Markowitz
- Return methodologies are ***not*** a good approximation/simplification of the problem
- Value that can be unlocked by full dynamic optimization is ***not*** trivial
- Also supports what we know – "reckless conservatism" in long term MVO based strategies ***is*** very harmful

Strategy	Profile A Gamma	Profile B Gamma	Profile A Gamma-equivalent Alpha	Profile B Gamma-equivalent Alpha
Static allocation - Conservative	37%	49%	0.73%	2.01%
Static allocation - Moderate	20%	20%	0.43%	0.92%
Static allocation - Aggressive	10%	8%	0.22%	0.37%

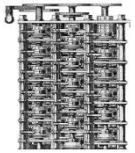


What About the Most Utility Efficient Markowitz Strategy?

- Many advice providers use MVO to set strategies and then test within the goal space
- This is still deeply inefficient and adds little to the straight aggressive Markowitz strategy
- Interestingly where utility maximization of Markowitz led to utility improvement it required a ***less*** aggressive strategy, contrary to the widely held layman's view that maximum risk trumps all else across a long enough horizon

	Profile A	Profile B
Dynamic	1977k	667k
Optimal static	984k	288k
Static Aggressive	890k	288k
Static Moderate	349k	-102k

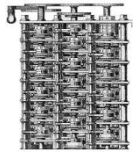
Objective/utility values



Dynamic Draw Downs

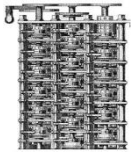
- Proper optimization of a fully dynamic draw down strategy **post retirement** makes a significant difference as well
- Basic mechanistic rules ***do not*** cut it and are very risky
  - For example, draw down only to a level ensuring no more than 50% ruin probability or spend a fixed proportion of your remaining pension pot
- The dynamic strategy improves the consumption plan ***and*** the quality of investment decisions now

Strategy	Profile A Gamma	Profile B Gamma	Profile A Gamma-equivalent Alpha	Profile B Gamma-equivalent Alpha
Fixed Spending	5%	26%	0.12%	1.18%
Fully Fixed	16%	88%	0.34%	3.14%



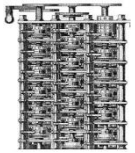
Importance of Flexible Decision Making

- The ability to flexibly react to outcomes makes a ***big*** difference
  - Better results/outcomes
  - Logical explanation of why/interpretation of asset allocations
  - Thus the 'parallel simulation'/ 'deterministic asset allocation'/ 'non-adaptive' asset allocation approach to optimization is ***not*** a representative practically useful simplification of the true problem
  - The argument that the flawed representation will be redone frequently – say triennially – is ***not*** a defence



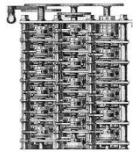
Flexible Decision Making Effectiveness

Strategy	Profile A Gamma	Profile B Gamma	Profile A Gamma-equivalent Alpha	Profile B Gamma-equivalent Alpha
Non-adaptive Dynamic	9%	6%	0.21%	0.30%
Static allocation - Conservative	37%	49%	0.73%	2.01%
Static allocation - Moderate	20%	20%	0.43%	0.92%
Static allocation - Aggressive	10%	8%	0.22%	0.37%
Fixed Spending	5%	26%	0.12%	1.18%
Fully Fixed	16%	88%	0.34%	3.14%

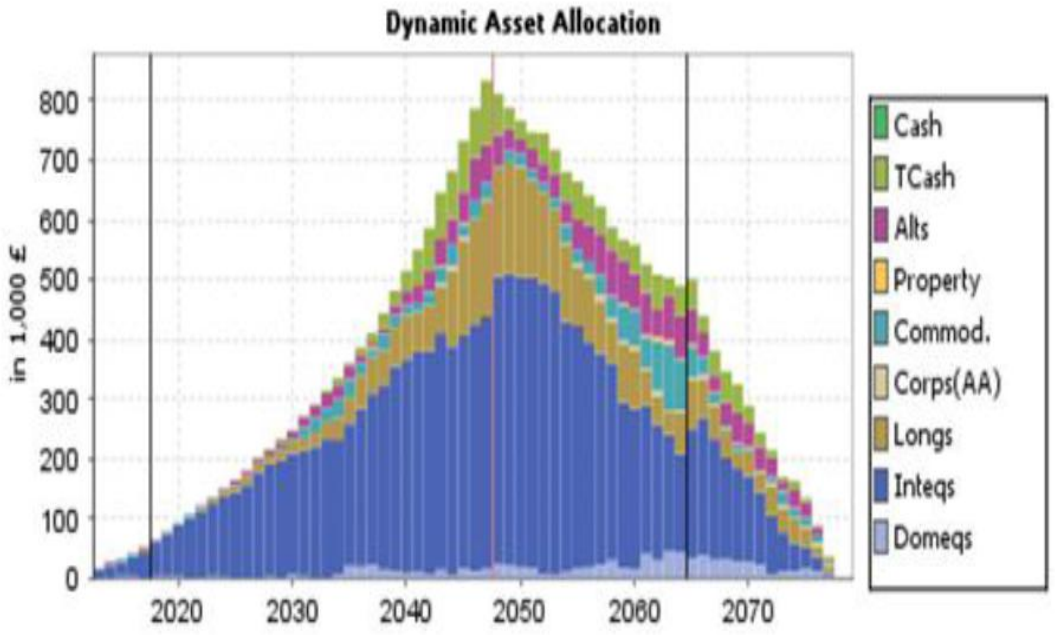


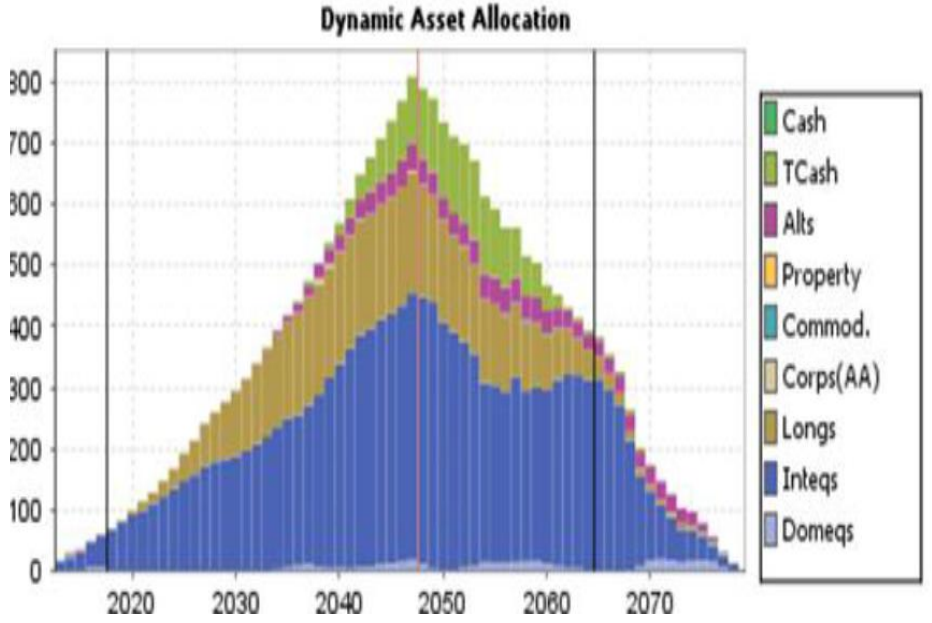
Initial Gap – man-in-the-street comparison measure

Strategy	Profile A	Profile B
Non-adaptive Dynamic	92k	101k
Static allocation - Conservative	**1500k**	600k
Static allocation - Moderate	350k	280k
Static allocation - Aggressive	115k	135k
Fixed Spending	18k	200k
Fully Fixed	200k	**1380k**



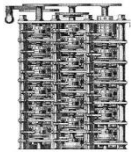
Dynamic vs Non-adaptive Dynamic Investment (aka best life staged product)





Capital Loss Risk Control

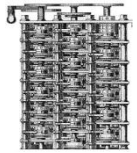
- Conventional thinking is "I must choose between risk control of liabilities and capital loss" because liability hedging is only possible through fixed income
- We find here that light capital 'guarantees' can be offered by the full dynamic strategy at almost no cost in terms of utility/liability efficiency
- We also find this is only possible when using the full dynamic approach – optimization without this fails to achieve capital preservation and goal achievement without massive costs
- Although the 15% shown is still a large portfolio loss it is comes nearly free. Most lay people unfortunately do value capital stability even if you explain the relation to liabilities is far more important and they are likely to value portfolio draw down control at virtually no cost even if it is limited control



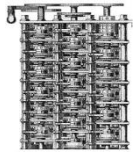
15% vs 100% Portfolio Draw Down Tolerance

Objective/utility values

Strategy	Portfolio Loss Tolerance	Profile A	Profile B
Dynamic	100%	1,997,466	671,329
Dynamic	15%	1,976,537	667,167
Static Moderate	100%	348,687	-102,070
Static Moderate	15%	348,686	-102,070
Static Aggressive	100%	1,302,173	344,773
Static Aggressive	15%	890,157	288,441
Non-adaptive Dynamic	100%	1,340,923	401,175
Non-adaptive Dynamic	15%	1,088,637	307,261



Conclusion



Summary Comparison of Dynamic With Fixed Investment Strategies

	Gamma
Dynamic	0 %
Fixed MVO allocation_ Conservative	37 %
Fixed MVO allocation_ Moderate	20 %
Fixed MVO allocation_ Aggressive (no risk mgt)	**10** %
Fixed spending	5 %

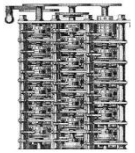
Young (30) profile gamma reduction of the constrained strategies relative to the dynamic strategy

	Gamma
Dynamic	0 %
Fixed allocation_ Conservative	49 %
Fixed allocation_ Moderate	20 %
Fixed allocation_ Aggressive (no risk mgt)	**8** %
Fixed spending	**26** %

Retired profile (65) gamma reduction of the constrained strategies relative to the dynamic strategy

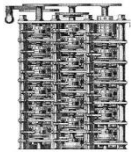
Morningstar *gamma* CE spend comparison
Banchett & Kaplan (2013)

Dempster, Kloppers, Medova, Osmolovskiy & Ustinov (2016)



Conclusions

- Dynamic stochastic programming is the paradigm for asset liability management which is applicable to individual household lifetime financial planning
- Ability to perform cash flow based optimal dynamic asset liability management over very long term random horizons in what-if mode
- Better idea of risks arising from future decisions – you can explicitly plan for them rather than adapting to outcomes as best you can as you go along myopically
- Demonstrably superior to current financial advisory portfolio return based advice and related heuristics in particular as used in robo advisors



References

- Medova *et al.* (2008). Individual asset-liability management. *Quantitative Finance* **8.9** 547-560
- Dempster, Mitra & Pflug, eds. (2009). *Quantitative Fund Management*. Chapman & Hall CRC
- Dempster &Medova (2011). Asset liability management for individual households. *British Actuarial Journal* **16.2** 405-464 (with discussion of Sessional Meeting of the Institute of Actuaries, London 22.2.10)
- Dempster & Medova (2011). Planning for retirement: Asset liability management for individuals. In: *Asset Liability Management Handbook*, Mitra & Schwaiger, eds. Palgrave Macmillan 409-432
- Bertocchi, Consigli & Dempster, eds. (2011). *Stochastic Optimization Methods in Finance and Energy*. Springer
- Dempster, Kloppers, Medova, Osmolovskiy & Ustinov (2016). Life cycle goal achievement or portfolio volatility reduction? *Journal of Portfolio Management* **42.2** 99-118
- Dempster (2016). Intelligent robo advice for life cycle planning. Commerz Bank *Thinking Ahead* **84** 40-45
- Dempster (2017). Intelligent financial planning for life. *Journal of Financial Innovation* **14** 165-177