InnoALM:

An Innovest Austrian Pension Fund

Financial Planning Model

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Joint paper with

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What is InnoALM?

- A multi-period stochastic linear programming model designed by Ziemba and implemented by Geyer with input from Herold and Kontriner
- For Innovest to use for Austrian pension funds
- A tool to analyze Tier 2 pension fund investment decisions

Why was it developed?

- To respond to the growing worldwide challenges of ageing populations and increased number of pensioners who put pressure on government services such as health care and Tier 1 national pensions
- To keep Innovest competitive in their high level fund management activities

Features of InnoALM

- A multiperiod stochastic linear programming framework with a flexible number of time periods of varying length.
- Generation and aggregation of multiperiod discrete probability scenarios for random return and other parameters
- Various forecasting models
- Scenario dependent correlations across asset classes
- Multiple co-variance matrices corresponding to differing market conditions
- Constraints reflect Austrian pension law and policy

Technical features include:

- Concave risk averse preference function maximizes expected present value of terminal wealth net of expected convex (piecewise linear) penalty costs for wealth and benchmark targets in each decision period.
- InnoALM user interface allows for visualization of key model outputs, the effect of input changes, growing pension benefits from increased deterministic wealth target violations, stochastic benchmark targets, security reserves, policy changes, etc.
- Solution process using the IBM OSL stochastic programming code is fast enough to generate virtually online decisions and results and allows for easy interaction of the user with the model to improve pension fund performance.

InnoALM *anticipates* and *reacts* to all market conditions: severe as well as normal

Description of the Pension Fund

Siemens AG Österreich is the largest privately owned industrial company in Austria. Turnover (EUR 2.4 Bn. in 1999) is generated in a wide range of business lines including information and communication networks, information and communication products, business services, energy and traveling technology, and medical equipment.

- The Siemens Pension fund, established in 1998, is the largest corporate pension plan in Austria and follows the defined contribution principle.
- More than 15.000 employees and 5.000 pensioners are members of the pension plan with about EUR 500 million in assets under management.
- Innovest Finanzdienstleistungs AG, which was founded in 1998, acts as the investment manager for the Siemens AG Österreich, the Siemens Pension Plan as well as for other institutional investors in Austria.
- With EUR 2.2 billion in assets under management, Innovest focuses on asset management for institutional money and pension funds.
- The fund was rated the 1st of 19 pension funds in Austria for the two-year 1999/2000 period

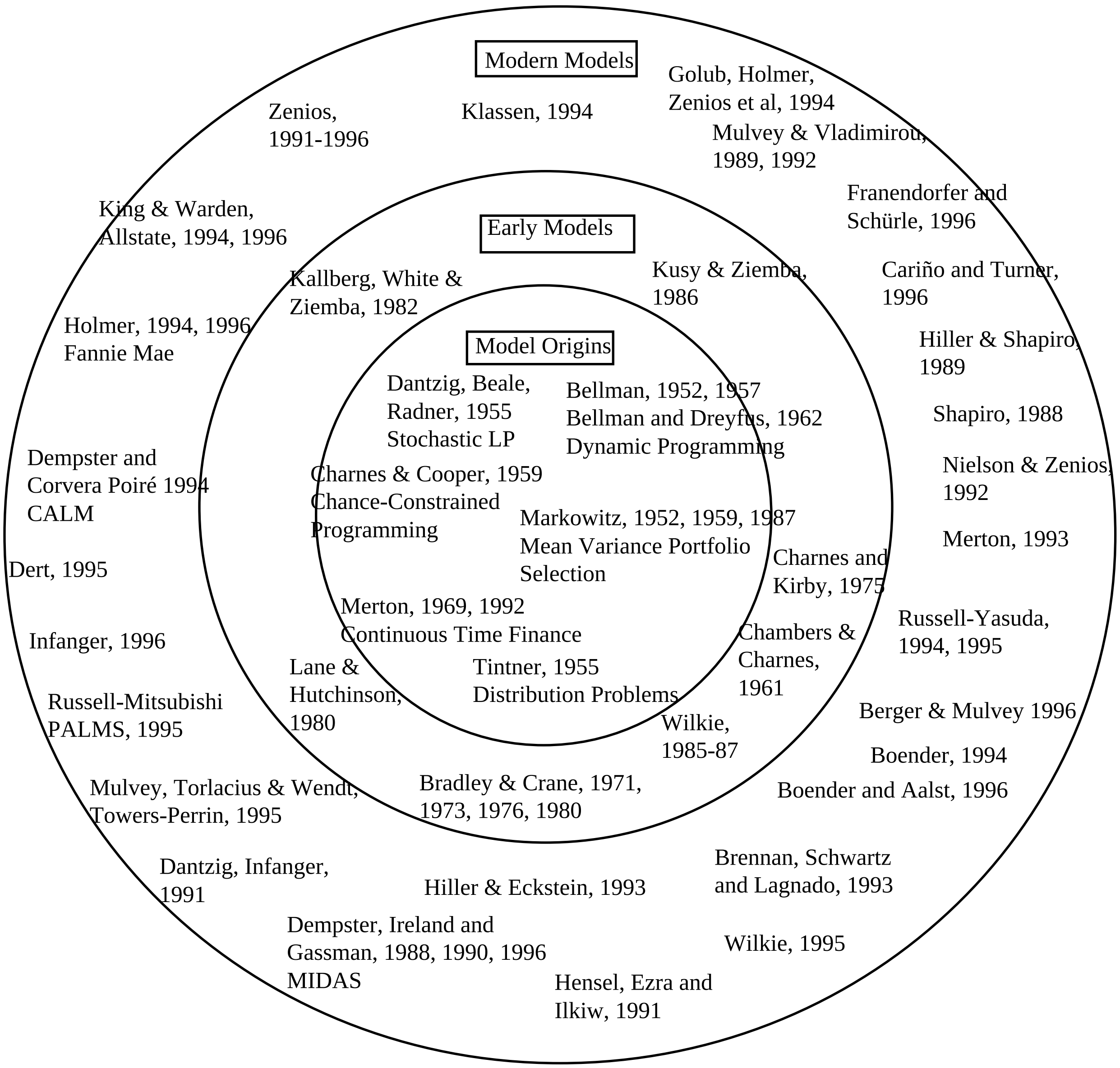
Factors that led Innovest to develop the pension fund asset-liability management model InnoALM.

- Changing demographics in Austria, Europe and the rest of the globe, are creating a higher ratio of retirees to working population.
- Growing financial burden on the government making it paramount that private employee pension plans be managed in the best possible way using systematic asset-liability management models as a tool in the decision making process.
- A myriad of uncertainties, possible future economic scenarios, stock, bond and other investments, transactions costs and liquidity, currency aspects, liability commitments
- Both Austrian pension fund law and company policy suggest that multiperiod stochastic linear programming is a good way to model these uncertainties.
- Faster computers have been a major factor in the development and use of such models, SP problems with millions of variables have been solved by my students Edirisinghe and Gassmann and by many others such as Dempster, Gonzio, Kouwenberg, Mulvey, Zenios, etc
- Good user friendly models now need to be developed that well represent the situation at hand and provide the essential information required quickly to those who need to make sound pension fund asset-liability decisions.

InnoALM and other such models allow pension funds to strategically plan and diversify their asset holdings across the world, keeping track of the various aspects relevant to the prudent operation of a company pension plan that is intended to provide retired employees a supplement to their government pensions.

History

- 1950s fundamentals
- 1970s early models ≈ 1975 work with students Kusy and Kallberg
- early 1990s Russell-Yasuda model and its successors
- late 1990s ability to solve very large problems
- 2000+ mini explosion in application models
- WTZ references Kusy + Ziemba (1986), Cariño-Ziemba et al (1994, 1998ab), Ziemba-Mulvey (1998) Worldwide ALM, CUP



Advantages of Multiperiod Stochastic Programming Approach

- This approach has a number of practical advantages over alternative approaches for asset & liability management as static mean-variance analysis (Sharpe and Tint, 1990), continuous time modeling (Rudolf and Ziemba, 2000), shortfall risk minimization (Leibowitz and Henriksson, 1988) and other approaches (Ziemba and Mulvey, 1998 and Samuelson, 1989).
- This approach includes more of the essential elements of the real problem.
- Insight follows from the study of alternative approaches and much of that theory is embedded in InnoALM.
- *Ex post* studies of pension fund performance over time such as Brinson, Hood and Beebower (1986), Hensel, Ezra and Iikiw (1991) and Blake, Lehmann and Timmermann (1999) focus on various possible sources of performance enhancement such as strategic asset allocation, market timing and security selection.
- These studies indicate that ***strategic asset allocation*** is the crucial variable in successful pension fund performance.

InnoALM provides a good procedure for implementing crucial aspects of pension fund management policies, constraints and goals to achieve superior long run performance while at the same time providing short-term risk management through diversification across various scenarios.

Project Team

- For the Russell Yasuda-Kasai model, we had a very large team and overhead cost was very high.
- At Innovest we were a team of four with Geyer implementing my ideas with Herold and Kontriner contributing guidance and information about the Austrian situation.
- The IBM OSL Stochastic Programming Code of Alan King was used with various interfaces allowing lower development costs [for a survey of codes see in forthcoming Wallace-Ziemba book, *Applications of Stochastic Programming*, a friendly users guide to SP modeling, computations and applications, SIAM MPS]

The success of InnoALM demonstrates that a small team of researchers with a limited budget can quickly produce a valuable modeling system that can easily be operated by non-stochastic programming specialists on a single PC.

The Pension Fund Situation in Austria and Europe

- Rapid ageing of the developed world’s populations - the *retiree group*, those 65 and older, will roughly double from about 20% to about 40% of compared to the *worker group*, those 15-64
- Better living conditions, more effective medical systems, a decline in fertility rates and low immigration into the Western world contribute to this ageing phenomenon.
- By 2030 ***two*** workers will have to support each pensioner compared with four now.

Projections of the elderly dependency ratio (65 and over as % of population 15-64), 1990-2030

Country	**1990**	**2010**	**2030**
Austria	**22.4**	**27.7**	**44.0**
Belgium	22.4	25.6	41.1
Denmark	22.7	24.9	37.7
Finland	19.7	24.3	41.1
France	20.8	24.6	39.1
Germany	21.7	30.3	49.2
Greece	21.2	28.8	40.9
Ireland	18.4	18.0	25.3
Italy	21.6	31.2	48.3
Luxembourg	19.9	25.9	40.2
Netherlands	19.1	24.2	45.1
Portugal	19.5	22.0	33.5
Spain	19.8	25.9	41.0
Sweden	27.6	29.1	39.4
UK	24.0	25.8	38.7
EU average	**21.4**	**25.9**	**40.3**

Source: Bos (1994)

EU ***State pensions*** (pillar 1) are about ***88% of total pension costs***.

- Demographics will have a major impact on public and private pension plans in Europe.
- Without a change in the policy towards financing methods of pension expenditures, future costs will increase significantly - especially in the public social security systems, which are usually based on the pay-as-you-go principle,.
- Without any changes the pension payouts will grow from 10% of GDP in 1997 to over 15% of GDP in 2030 for many EU countries.
- Contribution rates must be raised significantly to enable the public social security system to cope with this problem.

In the UK and Ireland, pension costs will remain stable over the projection period.

- These countries have pension schemes linked to employment (second pillar) and pension provisions taken out by individuals (third pillar) are well established.

OECD projections of pension costs, Pension expenditure/GDP

	1995	2000	2010	2020	2030	2040
Belgium	10.4	9.7	8.7	10.7	13.9	15.0
Denmark	6.8	6.4	7.6	9.3	10.9	11.6
Finland	10.1	9.5	10.7	15.2	17.8	18.0
France	10.6	9.8	9.7	11.6	13.5	14.3
Germany	11.1	11.5	11.8	12.3	16.5	18.4
Ireland	3.6	2.9	2.6	2.7	2.8	2.9
Italy	13.3	12.6	13.2	15.3	20.3	21.4
Netherlands	6.0	5.7	6.1	8.4	11.2	12.1
Portugal	7.1	6.9	8.1	9.6	13.0	15.2
Spain	10.0	9.8	10.0	11.3	14.1	16.8
Sweden	11.8	11.1	12.4	13.9	15.0	14.9
UK	4.5	4.5	5.2	5.1	5.5	5.0

Source: Rosevaere et al. (1996)

Pension fund assets as a percent of GDP are rather low, except for the UK, the Netherlands and to a lesser extent Ireland and Sweden.

- ***In 1997 only 7% of total pension payments for the whole EU were from pillar two and less from pillar three.***
- The Netherlands (32%) and the UK (28%) have more developed private pension fund systems.
- ***In Austria they were less than half of the EU average at barely 10% of GDP.***

Pension Fund Assets as a percentage of GDP in 1997, in bn. ECU

Countries	Assets	GDP	as a % of GDP
Austria	***20.9273***	***181.8278***	***11.51***
Belgium	10.3493	213.8373	4.84
Denmark	29.3019	143.7339	20.39
Finland	8.8766	103.6119	8.57
France	84.4193	1,229.0572	6.87
Germany	270.7216	1,865.3663	14.51
Greece	4.5854	105.0228	4.37
Ireland	34.4642	64.1071	53.76
Italy	21.5814	1,010.7227	2.14
Luxembourg	0.0283	13.6679	0.21
Netherlands	361.6643	320.0063	113.02
Portugal	9.3663	85.9758	10.89
Spain	18.6856	470.3538	3.97
Sweden	96.1839	202.3738	47.53
U.K.	891.2270	1,127.2971	79.06
Total EU	**1,862.3823**	**7,136.9617**	**26.09**

Source: European Federation for Retirement Provision (EFRP) (1996)

Effective private pension plans will need to play a more major role given the countries' demands for health care and other social services in addition to pensions.

- Reforms of the public pension systems will be necessary along with an effective environment for pillar 2 and 3 private pension systems.

InnoALM is a model for the effective operation of ***second pillar*** private pension funds in Austria.

- These funds usually work on a funded basis where the pension benefits depend on an employment contract or the pursuit of a particular profession.
- Schemes are administered by private institutions.
- Benefits are not guaranteed by the state.
- Employer pension schemes vary throughout Europe.
- Contributions to such systems are made by the employer and, on an optional basis, by employees.
- The contribution level may depend on the wage level or the position within a company.
- Defined contribution plans (DCP), have fixed contributions and the payout depends on the capital accumulation of the plan. Defined benefit plans (DBP) have payouts guaranteed by the company and the contribution is variable depending on the capital accumulation over time.

Risk Bearer

In DBP’s, the employer ***guarantees*** the pension payment - usually tied to some wage at or near retirement.

- If asset returns do not cover pension liabilities, the company would have to inject money into the pension plan.
- If asset returns of the plan are higher than required to fund liabilities, the company would gain, or equivalently reduce future contributions.

For DCPs, ***employees and pensioners bear the risk*** of low asset returns.

- ***Their pensions*** are not fixed and ***depend on the asset returns***.
- High returns will increase pensions and vice versa.
- There is no direct financial risk for the employer although with poor returns the employer would suffer negative image effects.
- The Siemens pension plan for Austria is a DCP but InnoALM is designed to handle either pension system.

Examples of national investment restrictions on pension plans

Country	**Investment Restrictions**
Germany	Max. 30% equities, max. 5% foreign bonds
Austria	Max. 40% equities, max. 45% foreign securities, min. 40% EURO bonds
France	Min. 50% EURO bonds
Portugal	Max. 35% equities
Sweden	Max. 25% equities
UK, US	Prudent man rule

Source: European Commission (1997)

In new proposals, the limit for worldwide equities would rise to 70% versus the current average of about 35% in EU countries.

Asset structure of European Pension funds, in percent, 1997

Countries	Equity	Fixed Income	Real Estate	Cash & STP	Other
Austria	4.1	82.4	1.8	1.6	10.0
Belgium	47.3	41.3	5.2	5.6	0.6
Denmark	23.2	58.6	5.3	1.8	11.1
Finland	13.8	55.0	13.0	18.2	0.0
France	12.6	43.1	7.9	6.5	29.9
Germany	9.0	75.0	13.0	3.0	0.0
Greece	7.0	62.9	8.3	21.8	0.0
Ireland	58.6	27.1	6.0	8.0	0.4
Italy	4.8	76.4	16.7	2.0	0.0
Luxembourg	23.7	59.0	0.0	6.4	11.0
Netherlands	36.8	51.3	5.2	1.5	5.2
Portugal	28.1	55.8	4.6	8.8	2.7
Spain	11.3	60.0	3.7	11.5	13.5
Sweden	40.3	53.5	5.4	0.8	0.1
U.K.	72.9	15.1	5.0	7.0	0.0
Total EU	53.6	32.8	5.8	5.2	2.7
US*	52	36	4	8	n.a.
Japan*	29	63	3	5	n.a.

* European Federation for Retirement Provision (EFRP) (1996)

Why do European pensions invest so much in bonds?

- More “mature” pillar 2 countries such as the UK and Ireland, which have managed portfolios for outside investors for a long time, have a higher equity exposure which may better reflect the long term aspect of pension obligations.
- In countries like Austria, Germany, Italy, Spain and France equity markets that were not developed until recently have pension plans that are invested more in local government bonds.
- Such asset structures reflect the attitude towards equities in various countries.
- The introduction of the EURO in 1999 is a first important step towards a more integrated capital market, especially for equities.
- In Austria, pension funds are now starting to increase their equity positions, but it will take some time to reach a structure similar to those in well established US, UK and Irish pension industries.
- Strict regulations, lack of investment products, fear of foreign investment, a short term outlook, and traditional investment behavior have led to this policy in the past.
- The regulations, and especially how they are perceived, are still not flexible enough to allow pension managers to diversify their portfolios across asset classes, currencies and worldwide markets.

Long run equities vs bond vs cash and short term market timing

Average real annualized pension fund net returns, percent, 1984-1993 for some EU countries and US

Subset of EU countries with restrictive investment styles		More advanced aggressive investment styles	
Belgium	8.8	Ireland	10.3
Denmark	6.3	UK	10.2
Germany	7.1	US	9.7
Netherlands	7.7		
Spain	7.0		
Average	***7.4***	***Average***	***10.1***

Source: European Commission (1997)

Hensel-Ziemba, 1942-1997, 56 years in Keim-Ziemba (2000)

A	100% US Small Caps Democrats	
	100% US Large Caps Republicans	14.1%/yr
B	60-40% Large Cap/Bonds	12.6%

A/B 24.5 times

- Studies such as Dimson, Marsh and Staunton (2000), Keim and Ziemba (2000), Siegel (1998) and Goetzmann and Jorion (1999) have indicated that over long periods equity returns have greatly outperformed bond returns.
- Moreover, the longer the period the more likely is this dominance to occur.
- How much to invest in cash, stocks and bonds over time is a deep and complex issue. For a theoretical analysis where the uncertainty of mean reversion is part of the model, see Barbaris (2000).

One thing is clear, equities have had an enormous advantage over cash and bonds during most past periods in most countries so that the optimal blend is *much more* equity than 5%.

Between 1982 and 1999 the return of equities over bonds was over 10% per year in EU countries.

- High equity returns of the distant past and the 1982-2000 bull market have led to valuations of price-earnings and other measures that in 1999-2001 were are at historically high levels in Europe, the US and elsewhere.
- Studies by Siegel (1999), Campbell and Shiller (1998), Berge and Ziemba (2000) and especially Shiller (2000) suggest that this outperformance is unsustainable and the weak equity return results in 2000 and 2001 are consistent with this view.

The big questions is: will interest rate cuts in the US and other countries lead to robust stock markets or will the poor returns last for years?

- It is unclear when higher returns will return and whether they will be very high in the 2001-2005 period.
- The specification of the benchmark (a linear combination of assets) around which the fund is to be evaluated greatly influences pension investment behavior.

InnoALM is designed to help pension fund managers prudently make these choices taking basically all aspects of the problem into account.

Austrian pension fund managers had considerably more flexibility in their asset allocation decisions than the above investment rules would indicate.

- If an investment vehicle is more than 50% invested in bonds than that vehicle is considered to be a bond fund. Investment in 45% equities and 55% in bond funds (whose average bond and stock weightings are 60-40), gives a fund’s average equity of 67%, which is similar to that of the higher performing UK managers.
- Moreover, currency hedged assets are considered to be Euro denominated.
- The minimum of 40% in Euro bonds is effectively a 40% limit on worldwide bonds but because of the above rules on weighting of assets, this limit is not really binding either.
- The 5% rule on option premium means that managers had effectively full freedom for worldwide asset allocations.
- Use of the rules was not typical by actual pension fund managers. In some scenarios such allocations away from typical pension fund asset allocation in other Austrian pension funds could have led to disaster.

Without being armed with a model such as InnoALM which calculates the possible consequences of asset weight decisions, it was safest for managers to go with the crowd.

Formulating the InnoALM as a multistage stochastic linear programming model

- Model determines the optimal purchases and sales for each of N assets in each of T planning periods.
- Typical asset classes used at Innovest are US, Pacific, European, and Emerging Market equities and US, UK, Japanese and European bonds.
- Objective is to maximize expected terminal wealth less convex penalty costs subject to various constraints.

  The stochastic program has a concave risk averse utility function subject to linear constraints.
- Decision variables are wealth (after transactions costs) W_{it}, purchases P_{it} and sales S_{it} for each asset *(i=1,...,N).*
- Purchases and sales take place at stages $t=0,...,T-1$.
- Returns are associated with time intervals. $\tilde{R}_{it}$ $(t=1, ...,T)$ are the (random) gross returns for asset i between t–1 and T. Tilda‘s denote scenario-dependent random parameters or decision variables.
- Uncertainty is introduced by generating multiperiod scenarios using statistical properties of the asset's returns.
- Optimal allocations are from a stochastic linear program using the IBMOSL library routines.
- Except for stage 0, purchases and sales are scenario dependent.
- Non-anticipatory constraints are imposed to guarantee that a decision made at a specific node is identical for all scenarios leaving that node. That is the future cannot be anticipated.

- Wealth accumulation

$$W_{i0} = W_i^{init} + P_{i0} - S_{i0}, \qquad t=0$$

$$\tilde{W}_{it} = \tilde{R}_{it} W_{i0} + \tilde{P}_{i1} - \tilde{S}_{i1}, \qquad t=1$$

$$\tilde{W}_{it} = \tilde{R}_{it} \tilde{W}_{i,t-1} + \tilde{P}_{it} - \tilde{S}_{it}, \qquad t=2,...,T-1$$

$$\tilde{W}_{iT} = \tilde{R}_{it} \tilde{W}_{i,T-1}, \qquad t=T.$$

w_i^{init} is the prespecified initial value of asset *i*.

- Budget constraints are

$$\sum_{i=1}^{N} P_{i0}(1+tcp_i) = \sum_{i=1}^{N} S_{i0}(1-tcs_i) + C_0 \qquad t=0,$$

$$\sum_{i=1}^{N} \tilde{P}_{it}(1+tcp_i) = \sum_{i=1}^{N} \tilde{S}_{it}(1-tcs_i) + C_t \qquad t=1,...,T-1,$$

tcp_i and tcs_i denote asset-specific linear transaction-costs for purchases and sales, and C_t is the fixed (non-random) net cashflow

- Short sales are not allowed, sales are no greater than current holdings

$$S_{i0} \le W_i^{init} \qquad i=1,...,N \quad t=0,$$

$$\tilde{S}_{it} \le \tilde{R}_t \tilde{W}_{i,t-1} \qquad i=1,...,N \quad t=1,...,T-1.$$

- Model has built in bounds on portfolio weights so that the user may specify the desired restrictions.
- Impact of such decisions may be investigated using the dual prices obtained from the optimization of the large linear program in extensive.
- α_k is the maximum percentage of asset k

$$\tilde{W}_{kt} - \alpha_k \sum_{i=1}^{N} \tilde{W}_{it} \leq 0 \qquad t=0,\ldots,T\text{-}1.$$

- β_k is the minimum percentage of asset k

$$\tilde{W}_{kt} + \beta_k \sum_{i=1}^{N} \tilde{W}_{it} \leq 0 \qquad t=0,\ldots,T\text{-}1.$$

- Constraints on linear combinations of assets

$$\sum_{i \in A_l} \tilde{W}_{it} - \gamma_A \sum_{i=1}^{N} \tilde{W}_{it} \leq 0,$$

$$-\sum_{i \in B_p} \tilde{W}_{it} + \delta_B \sum_{i=1}^{N} \tilde{W}_{it}, \qquad t=0, \ldots, T-1$$

where A_l and B_p are the subsets of assets i=1, …, N

The α_k’s, β_k’s, γ_A’s, δ_B’s, A_l ‘s and B_p’s may be time dependent.

In practice, Austrian, Germany and other European Union countries have specified restrictions that vary from country to country but not over time.

- Austrian limits:

  a maximum of 40% in total equities

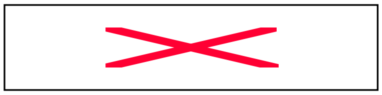
  a maximum of 45% in foreign securities

  a minimum of 40% in Euro currency bonds, and

  a maximum 5% of total premiums in non-currency hedged option short and long positions.

- Typically, $\overline{W}_t$, the wealth target at stage t, is assumed to grow 7.5% in each period. This is a deterministic target goal for the increase in the pension fund's assets assuming the number of employees in the pension fund is in a steady state.

- Wealth targets

 *t=1,...,T,*

  where $\tilde{M}_t^W \geq 0$ is the wealth-target shortfall or slack variable.

- Benchmark targets $\tilde{B}_t$ are scenario dependent, based on stochastic asset returns and on fixed weights defining the benchmark portfolio.

  $$\sum_{i=1}^{N} \tilde{W}_{it} + \tilde{M}_t^B \; ? \; \tilde{B}_t \quad t=1,\ldots,T,$$

  the variables $\tilde{M}_t^B$ equal the benchmark-target shortfalls.

- Shortfalls are also penalized by means of a piecewise linear convex risk measure, which may differ from the penalty function for wealth targets.

- If total wealth is above the target a percentage γ, typically 0.1, of the exceeding amount is allocated to the reserve account. Thus wealth targets for future stages are further increased. For that purpose additional non-negative decision variables $\tilde{D}_t$ are introduced and the wealth target constraints above become

  $$\sum_{i=1}^{N} (\tilde{W}_{it} - \tilde{P}_{it} + \tilde{S}_{it}) - \tilde{D}_t + \tilde{M}_t^W = \overline{W}_t + \sum_{j=1}^{t-1} \gamma \tilde{D}_{t-j}, \quad t=1,\ldots,T-1, \text{ where } \tilde{D}_1 = 0.$$

- Since actual pension payments are based on wealth levels, increasing these levels is tantamount to increasing pension payments.

- Deterministic target increases are typically targeted at 7.5% per year.

- Actual reserves generated by the stochastic benchmark targets provide security for the pension plans increase of actual pension payments at each stage t.

- The pension plan’s concave risk averse objective function is to maximize the expected present value of terminal wealth in period T net of expected penalty costs captured by the convex risk measure:

$$\text{Max } E_S \left[d_T \sum_{i=1}^{N} \tilde{W}_{iT} - \lambda \sum_{t=1}^{T} d_t w_t \sum_{j=1}^{2} v_j c_j(\tilde{M}_t^j) \right],$$

where $c_j(\cdot)$ ($j=\{W,B\}$) are the penalty functions for wealth- and benchmark-targets.

- The u_{jt} are weights attached to wealth- and benchmark target-shortfalls for each stage. v_j are overall weights for the two types of shortfalls.
- w_t are overall weights for total shortfalls of each stage.
- Weights are normalized

$$v_1 + v_2 = 1 \qquad \sum_{t=1}^{T} v_t = T.$$

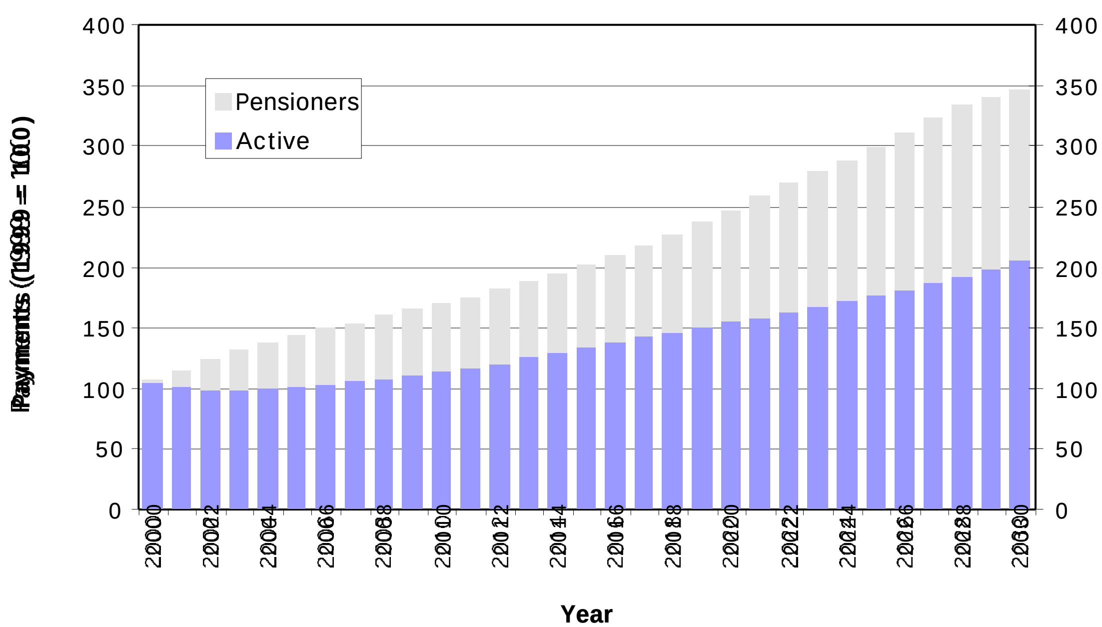
- $d_t = (1+r)^{-t}$, are discount factors and expectation is over T period scenarios S.
- Usually the interest rate, *r*, is the three or six month Treasury-bill rate. Campbell and Viceira (1998) argue that, in a multiperiod world, the proper risk-free asset is an inflation-indexed annuity rather than the short dated T-bill. Analysis based on a model where agents desire to hedge against unanticipated changes in the real rate of interest.
- Ten-year inflation-index bonds are then suggested for *r* as their duration closely approximates the indexed annuity.

Liability side of the Siemens Pension Plan

- Employees, for which Siemens is contributing payments using DCP
- Retired employees receiving pension payments.
- Simulation of the liabilities for a 30-year horizon ***assuming***:
- Active employees are in steady state; staff replaced by a new employee with the same qualification and sex.
- Salary is increasing 3.5 % to 4.5% annually.
- Annual Pension Plan contributions are a fixed fraction of salary
- The set of retired employees is modeled according to mortality and marital tables
- Widows are entitled to 60% of the pension payments.
- Retired employees are receiving pension payments after reaching age 65 for men and 60 for women in accordance with the legal Pension Plan.
- Pension payments to retired employees are calculated based upon the individually accumulated contribution and performance during active employment; for the annuities a discount rate of 6% is used.
- Indexation of pension payments is set equal to 1.5% per annum to compensate for inflation.

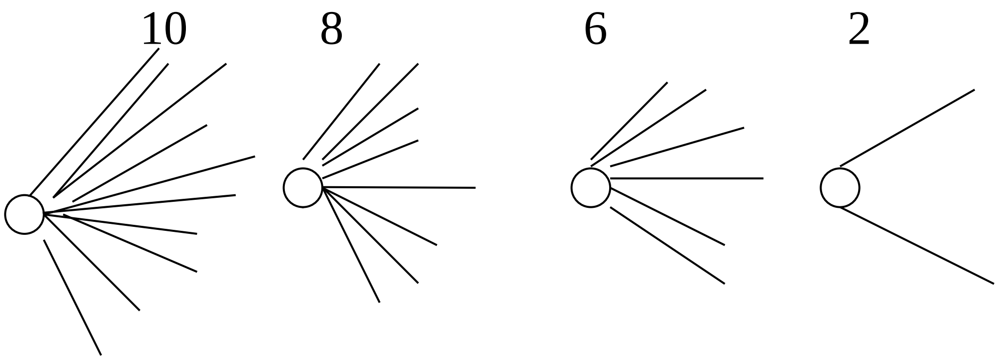
- Assets grow 7.5% per year to match liability growth.
- Liabilities related to active employees are simulated on an individual level, due to the steady state assumption.
- Growth reflects only salary increases.
- Pensioners are likely to increase as currently active employees are retiring.
- Besides the target growth of assets, another output of the simulation of liabilities is the estimated annual net cash flow of plan contributions minus payments.
- Number of pensioners rising faster than plan payments.
- These cash flows are negative.
- Plan is declining in size.

Estimated payment growth breakdown active and retired employees, 2000-2030



Source: Innovest (2000)

Scenario Generation and Statistical Inputs



Scenario tree with a 10-8-6-2 node structure (960 total scenarios)

- Discrete scenarios
- Scenario dependent correlation matrices
- Fat tails/normal, t, general
- Means, standard deviations, correlations
- Embedded data
  1986-2000 bonds
  1970-2000 equity
  1992-2000 emerging market equity (also to 1800 for US and US)
- James-Stein mean reversion adjustments

Implementation, output and sample results

- An Excelä spreadsheet is the user interface.

- The spreadsheet is used to select assets, define the number of periods and the scenario node-structure.

- The user specifies the wealth targets, cash in- and out-flows and the asset weights that define the benchmark portfolio (if any).

- The input-file contains a sheet with historical data and sheets to specify expected returns, standard deviations, correlation matrices and steering parameters.

Elements of InnoALM

Front-end user interface (Excel)

- Periods (targets, node structure, fixed cash-flows, ...)
- Assets (selection, initial values, transaction costs, ...
- Liability data
- Statistics (mean, standard deviation, correlation)
- Bounds
- Weights
- Historical data
- Options
- Controls

GAUSS

- read input
- compute statistics
- simulation returns (generate scenarios)
- generate SMPS files

IBMOSL solver

- read SMPS input files
- solve the problem
- generate output file (solutions for all nodes and variables)

Rear-end user interface (GAUSS)

- read optimal solutions
- generate tables and graphs
- retain key variables in memory to allow for further analyses

Example

- Four asset classes (stocks Europe, stocks US, bonds Europe, and bonds US) with five periods (six stages).
- The periods are twice 1 year, twice 2 years and 4 years (10 years in total
- 10000 scenarios based on a 100-5-5-2-2 node structure.
- The wealth target grows at an annual rate of 7.5%.
- R_A=4 and the discount factor equals 5.
- Theory: Kallberg-Ziemba (1983)

Means, standard deviations & correlations based on 1986-2000 data

		Stocks Europe	Stocks US	Bonds Europe	Bonds US
normal periods (70% of the time)	Stocks US	0.763			
	Bonds Europe	0.291	0.236		
	Bonds US	0.493	0.763	0.286	
	standard deviation	17.5	18.3	3.8	11.3
flat & declining markets (20% of the time)	Stocks US	0.784			
	Bonds Europe	0.178	0.107		
	Bonds US	0.438	0.718	0.166	
	standard deviation	18.3	21.1	4.1	12.2
crash periods (10% of the time)	Stocks US	0.832			
	Bonds Europe	-0.075	-0.182		
	Bonds US	0.315	0.618	-0.104	
	standard deviation	21.7	27.1	4.4	12.9
all periods	mean	12.0	13.0	6.5	7.2

N return distributions normally distributed and no mixing of correlations matrices is performed

NM mixing correlations; 10% of the time, markets are extremely volatile, 20 % of the time there are flat or declining markets and 70% of the time markets are assumed to be typically correlated. Mixing correlations also implies mixing different levels of volatility.

TM the same mixing proportions but equities have fat-tails. Annual returns of all asset classes are well described by a joint normal distribution. Monthly returns for equities are clearly non-normal. Equity returns have a *t*-distribution with 5 degrees of freedom.

TMCall assumptions of case TM but add Innovest's constraints on asset weights. Eurobonds must be at least 40% and equity at most 40%.

Optimal initial asset weights at stage 0 obtained under various assumptions

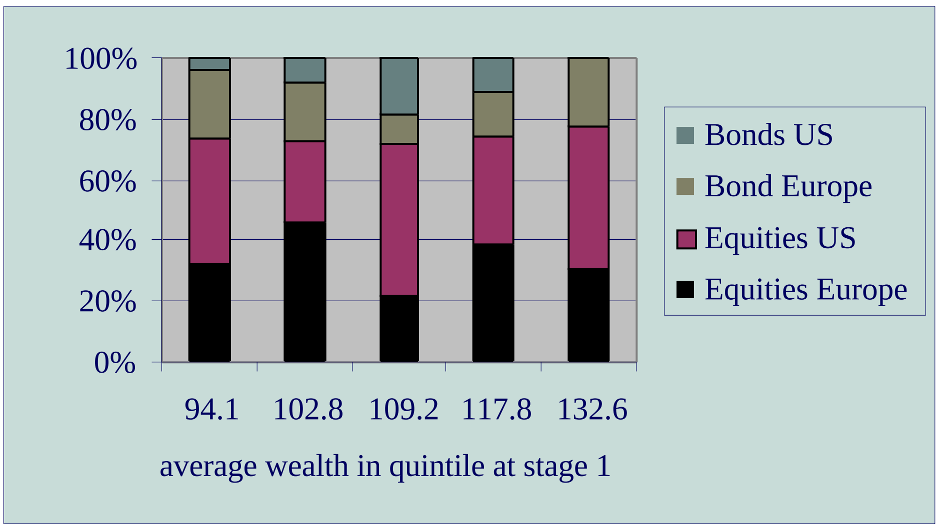
	Stocks Europe	Stocks US	Bonds Europe	Bonds US
single-period, mean-variance optimal weights	15.6%	39.7%	44.7%	0.0%
case N: no mixing (only normal periods);normal distributions	5.3%	48.1%	46.7%	0.0%
case NM: mixing correlations (70-20-10); normal distributions	46.2%	49.6%	4.2%	0.0%
case TM: mixing correlations (70-20-10); t-distributions for stocks	56.1%	26.2%	17.7%	0.0%
case TMC: mixing correlations (70%-20%-10%); t-distributions for stocks; constraints on asset weights	27.7%	12.3%	60.0%	0.0%

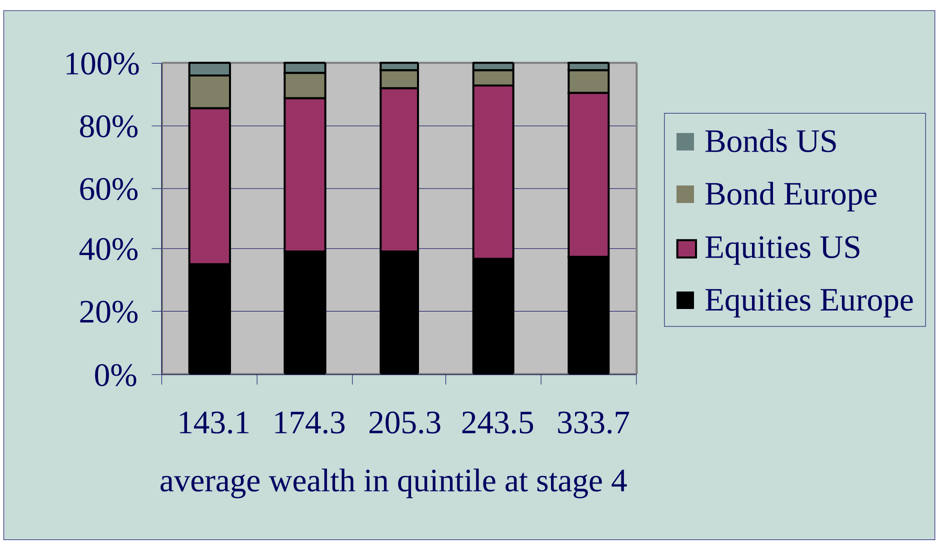
Expected portfolio weights at the final stage in various cases.

	Stocks Europe	Stocks US	Bonds Europe	Bonds US
case N	35.8%	53.5%	7.8%	3.0%
case NM	38.7%	51.8%	6.1%	3.3%
case TM	38.7%	53.3%	5.6%	2.4%
case TMC	17.7%	24.1%	46.2%	12.0%

- Break down the rebalancing decisions at later stages into groups of achieved wealth level.
- This reveals the 'decision rule' implied by the model depending on the current state.
- Quintiles of wealth were formed at stage 1 and the average optimal weights assigned to each quintile were computed.

Optimal weights conditional on the average level of portfolio wealth at stage 1 and stage 4.





Target wealth and expected total wealth by stage

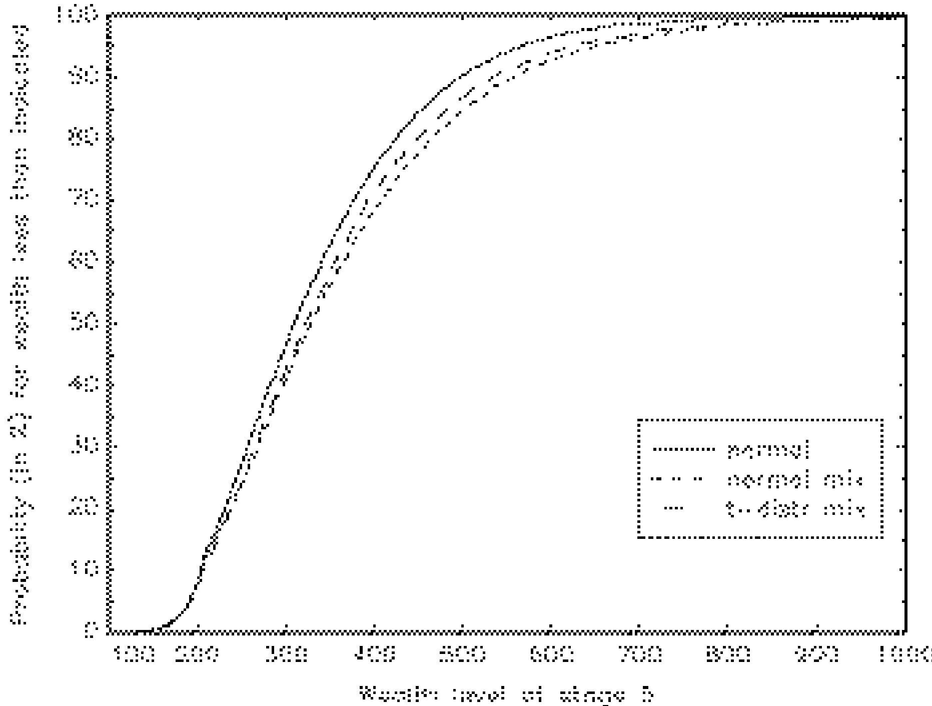
	stage 1	stage 2	stage 3	stage 4	stage 5
target	107.5	115.6	133.5	154.3	206.1
case N	109.9	126.3	161.0	211.4	334.1
case NM	112.3	130.4	168.2	224.6	362.3
case TM	111.3	128.4	165.9	220.1	353.8
case TMC	108.8	120.3	144.4	176.0	248.9

Probabilities for wealth target shortfalls by stage

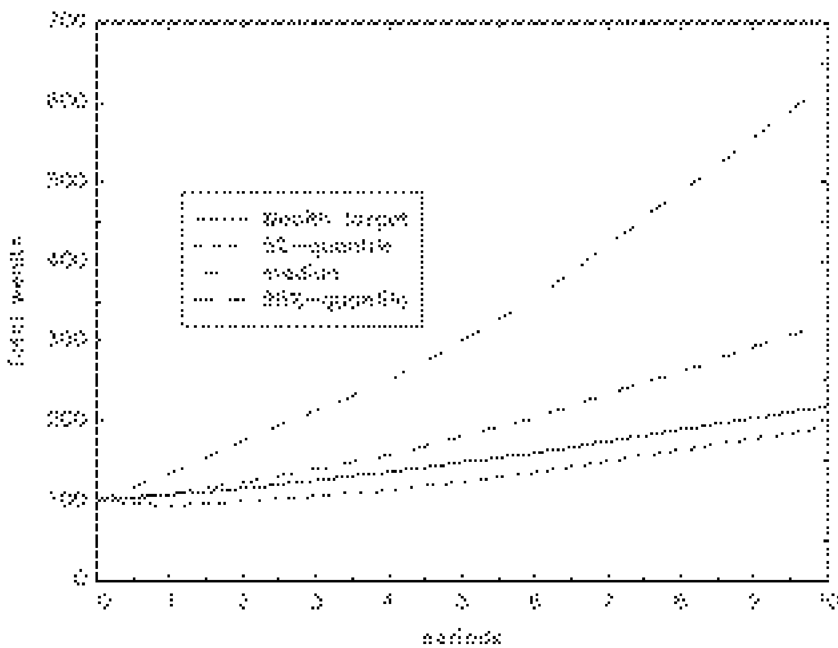
	stage 1	stage 2	stage 3	stage 4	stage 5
case N	38.0%	30.6%	25.6%	17.2%	12.9%
case NM	40.8%	30.7%	25.7%	16.8%	11.9%
case TM	40.9%	33.3%	25.0%	16.9%	10.8%
case TMC	43.1%	34.5%	31.5%	24.9%	22.2%

- The constraints in TMC lead to lower expected total wealth throughout the horizon under the 1986-2000 data assumptions
- Probabilities of shortfalls are not that small although they decline over time.
- Higher penalty costs are needed to lower these probabilities if they are unacceptable.

Probability terminal wealth is below various target levels under various assumptions.



Total wealth over time for case TM (t-distributions with mixing correlations).

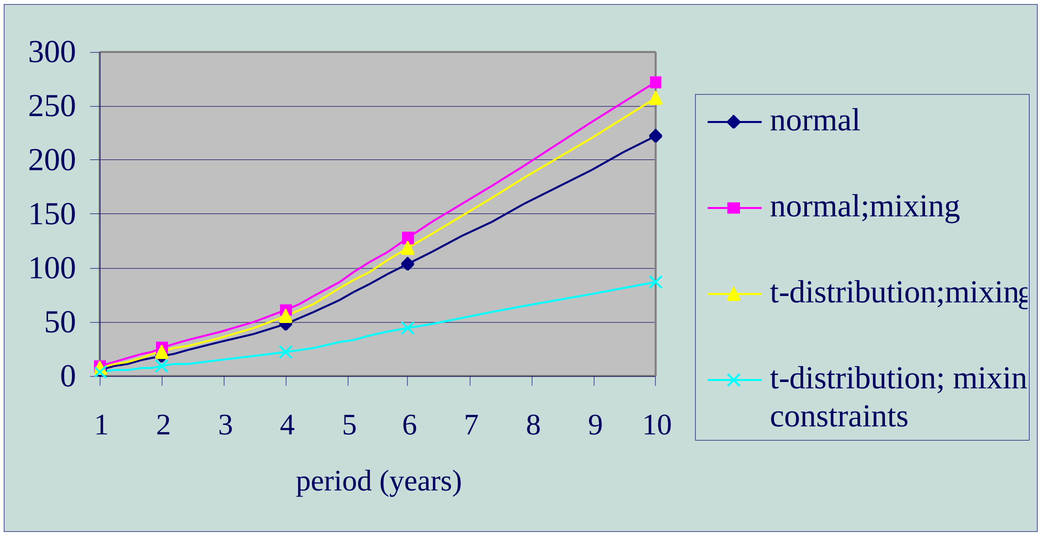


- If the level of portfolio wealth exceeds the target, the surplus $\tilde{D}_j$ is allocated to a reserve account
- The expected value of reserves at stage *t* is computed from $\sum_{j=1}^{t} \tilde{D}_j$
- These values are in monetary units given an initial wealth level of 100. They can be put into context by comparing them to the wealth targets.
- For the unconstrained cases (N, NM and TM) expected reserves can go up to 130% of the target level at the final stage.
- Depending on the scenario the reserves can be as high as 2500. Their standard deviation (across scenarios) ranges from 10 at the first stage to 250 at the final stage.

Expected reserves by stage, w_0=100

	stage 1	stage 2	stage 3	stage 4	stage 5
case N	5	19	48	103	222
case NM	9	26	62	128	273
case TM	7	23	56	119	257
case TMC	4	10	23	45	87

Development of expected reserves across the planning horizon.

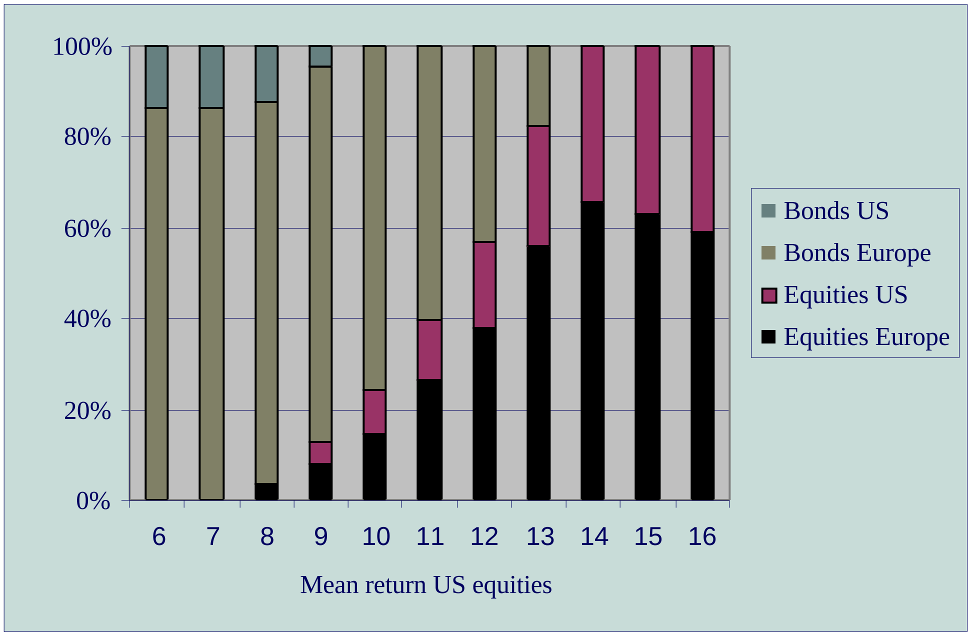


Who is right? Abby Cohen/WTZ or Bob Shiller or ??

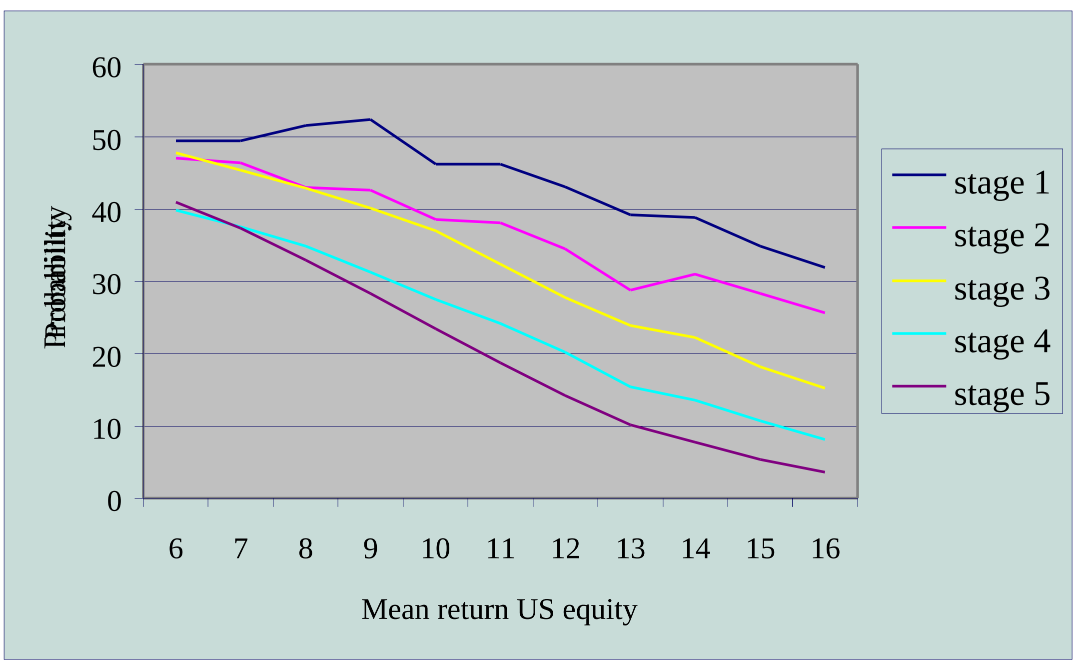
The effect associated with changing the forecasted future means of equity returns.

- Econometric model shows that the future mean return for US equities is some value.
- The parameterized mean is assumed to be 6 to 16%.
- The mean of European equities is adjusted to maintain the relative means from the 1986-1990 data: the ratio of European and US equity means is 12/13.
- Retain all other assumptions of case TM (t-distribution and mixing correlations).

Optimal asset weights at stage 0 for varying levels of US equity means.



Probability for wealth target shortfall at all stages for varying levels of US equity means.



The impact of the design of the scenario tree and the number of stages.

- 10000 scenarios generated according to 100x20x5
- using periods of length one, three and six years (total ten years).
- same assumptions about returns statistics and consider case TM.
- A slightly more cautious policy is implemented if there are less opportunities to rebalance the portfolio (19.3% versus 17.7% weight of bonds).

Comparing optimal portfolio weights at stage 0 and at the final stage for a three-period and a five-period problem (10000 scenarios each).

	Stocks Europe	Stocks US	Bonds Europe	Bonds US
stage 0 3 periods	49.7%	31.0%	19.3%	0.0%
stage 0 5 periods	56.1%	26.2%	17.7%	0.0%
final stage 3 periods	38.0%	58.6%	2.8%	0.6%
final stage 5 periods	38.7%	53.3%	5.6%	2.4%

Conclusions and final remarks

- InnoALM is a tool to evaluate pension fund asset allocation decisions.
- Multiple period scenarios/fat tails/uncertain means.
- Ability to make decision recommendations taking into account goals and constraints of the pension fund.
- Provides useful insight to pension fund allocation committee.
- Ability to see in advance the likely results of particular policy changes and asset return realizations.
- Gives more confidence to policy changes and recommends more equity and less bonds than has traditionally been the case in Austria.

InnoALM: An Innovest Austrian Pension Fund. Financial Planning Model. William T. Ziemba. University of British Columbia Joint paper with. Alois Geyer, University of Economics, Vienna, Austria Wolfgang Herold and Konrad Kontriner, Innovest, Vienna, Austria. What is InnoALM? 2.Â â€¢ InnoALM user interface allows for visualization of key model outputs, the effect of input changes, growing pension benefits from increased deterministic wealth target violations, stochastic benchmark targets, security reserves, policy changes, etc. â€¢ Solution process using the IBM OSL stochastic programming code is fast enough to generate virtually online decisions and results and allows for easy interaction of the user with the model to improve pension fund performance. The Innovest Austrian Pension Fund Financial Planning Model InnoALM. Operations Research 56(4), 797â€"810. Gondzio, J. and R. Kouwenberg (2001).Â Optimal Scenario Tree Generation for Multiperiod Financial Planning. Mathematical Programming 89(2), 251 â€" 271. Rockafellar, R., S. Uryasev, and M. Zabarankin (2006). Abstract This paper describes the financial planning model InnoALM we developed ,at Innovest for the Austrian pension fund of the electronics firm Siemens. The model uses a multiperiod,stochastic linear programming ,framework ,with a flexible number ,of time ,periods of varying ,length. Uncertainty is modeled ,using multiperiod discrete probability scenarios for random ,return and other model parameters. The correlations across asset classes, of bonds, stocks, cash and other financial instruments, are state dependent using multiple correlation matrices that correspond to differing market condi The Innovest Austrian Pension Fund Financial Planning Model InnoALM. The Innovest Austrian Pension Fund Financial Planning Model InnoALM (pp. 797-810). Alois Geyer and William T. Ziemba. https://www.jstor.org/stable/25147232.Â Multitask and Multistage Production Planning and Scheduling for Process Industries (pp. 1010-1025). Francesco Gaglioppa, Lisa A. Miller and Saif Benjaafar. https://www.jstor.org/stable/25147245.