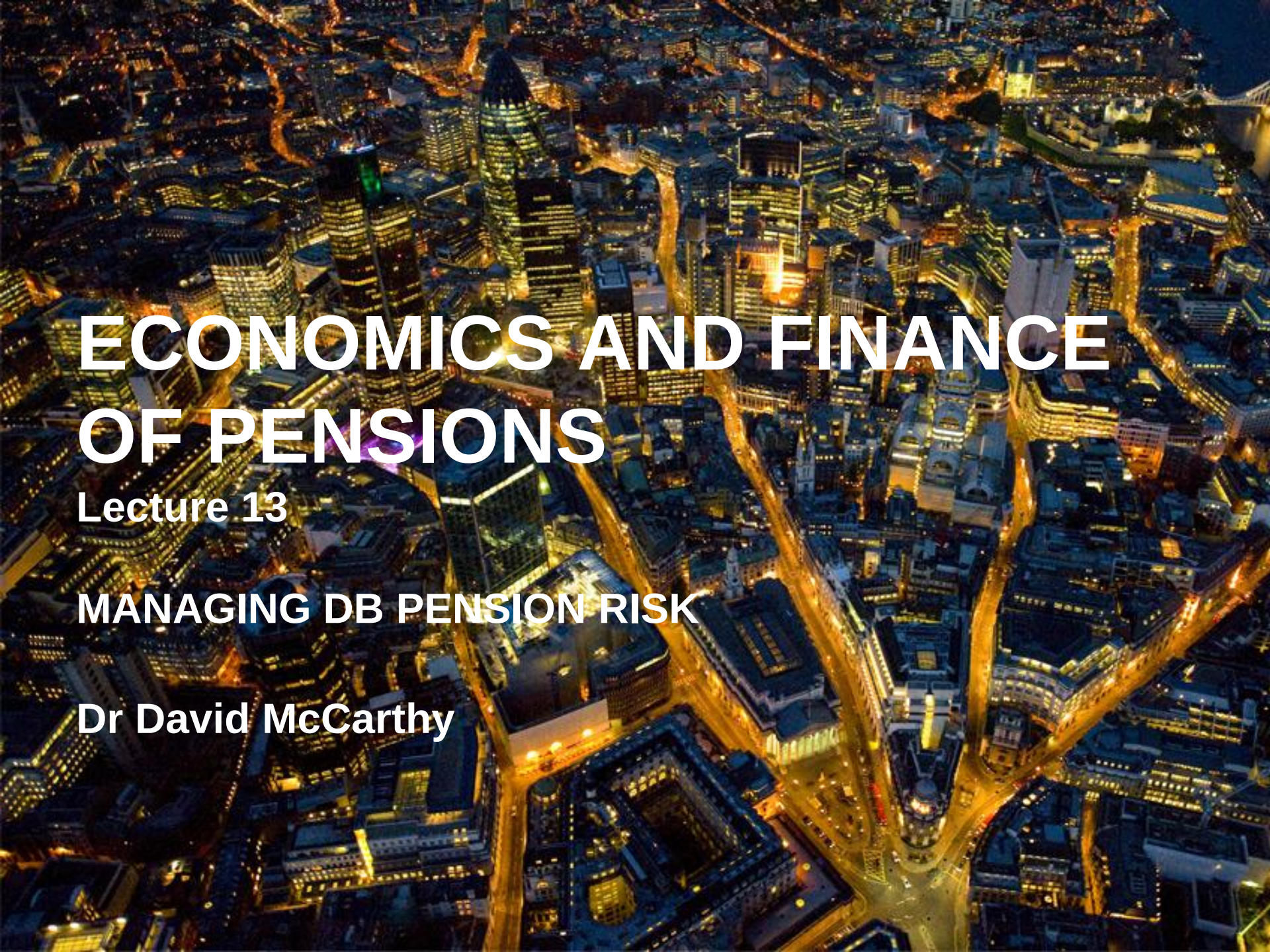


ECONOMICS AND FINANCE OF PENSIONS

Lecture 13

MANAGING DB PENSION RISK

Dr David McCarthy

Lecture outline

- We will concentrate on these four methods of managing pension risk:
  - Changing the asset allocation of the scheme
  - Changing sponsor financial structure (e.g. changing firm leverage and/or contributing to the scheme)
  - Liability management
  - Reinsurance / securitisation / buyout
- Some of these are largely available to the sponsor, and some to the trustees
  - Which tool is largely the province of which party?

What have we done?

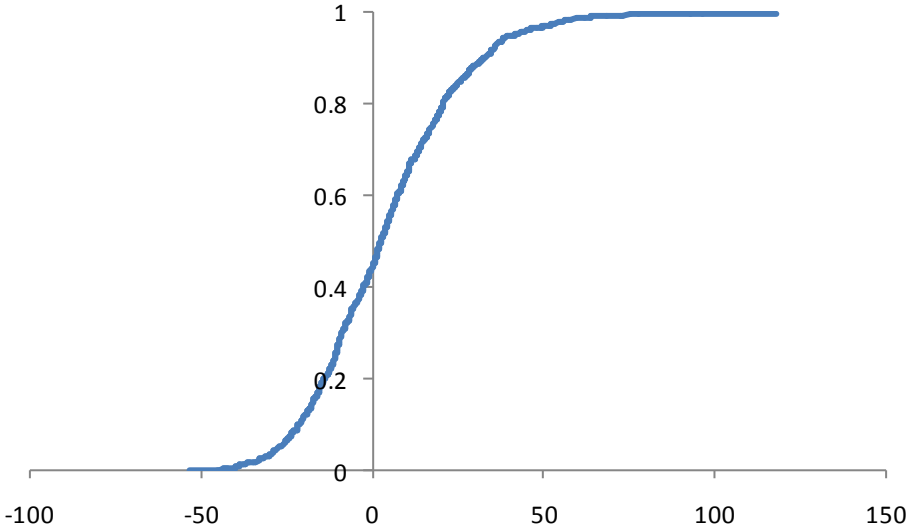
- Imagine that you have built an ALM of a pension scheme and a sponsor, and you want to use the ALM to advise the trustees and the sponsor about how large the risk they are exposed to is, and how they can manage it
- We now use the model to investigate the effects of using our different risk management tools on the cash flows borne by each party
  - We can express this either as a market-consistent price or as a distribution of cash flows

Summaries of outcomes

- We need to find a way to summarise the outcome of the cash-flow model to each party (they will be different)
  - Histogram
  - Expected value and standard deviation
  - Market price of hedging portfolio
  - VaR
  - Probability of shortfall / surplus
  - Expected value of shortfall
- Need also to choose a time horizon
  - Shorter is probably better

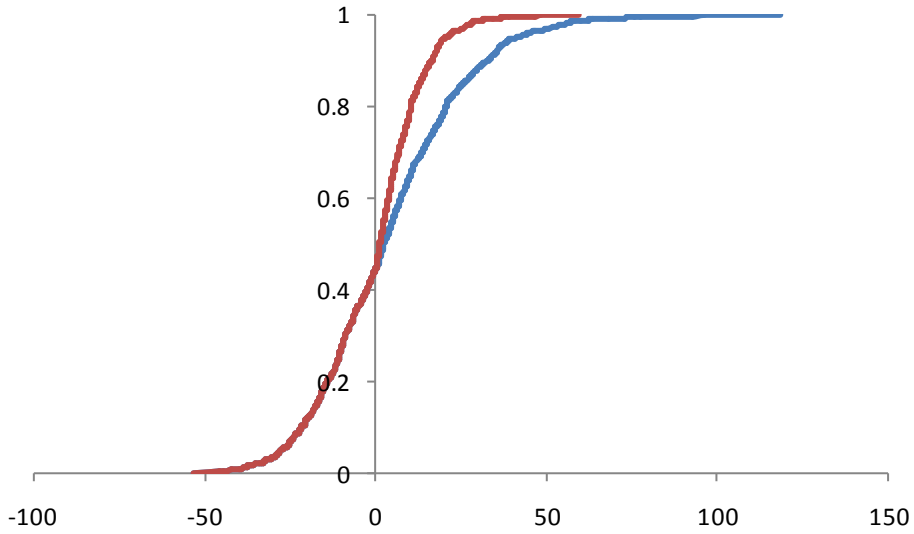
Example

- A scheme is invested 100% in equities, liabilities increase at the bond rate
- Assuming that bonds return 5%, equities return 9% with a standard deviation of 20%, the distribution of likely surplus in a year's time (assuming the scheme is fully funded today) is given by:
  - Average = +4.41
  - St. dev = 21.55
  - What is the market price of this set of risky cash flows?
  - How will this change if we change the investment mix?



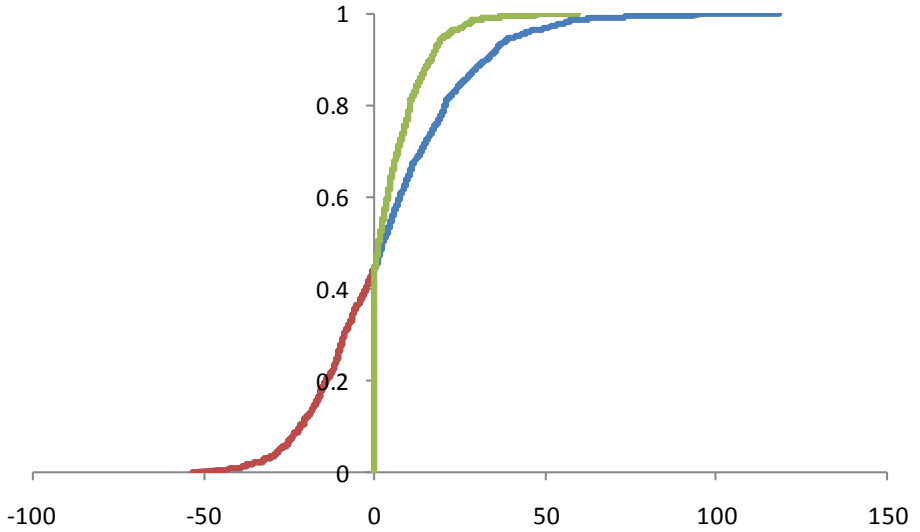
Dividing cash flows up

- Imagine the sponsor has the obligation to pay the shortfall, and the surplus is shared equally between the members and the sponsor
  - Sponsor's cash flows now look like this (red line):
  - Mean = -1.19, st. dev = 14.88
  - What is the market price?
  - How will it change if we change the investment mix?



Dividing cash flows up

- We can add the members cash flows (green
- Mean = 5.22, std. dev = 7.66
  - What is the market price?



- In the next slide I have shown various risk measures for these cash flows
- Which do you think is most meaningful?
- Why?

Measures of risk

	Employer	Employee	Total
Mean	-1.19	5.23	4.03
Std dev	14.9	7.7	21.6
95% VaR	-27.7	0.0	-27.7
99% VaR	-39.1	0.0	-39.1
Expected shortfall	-14.4	0.0	-14.4
Probability of shortfall	0.44	0.0	0.44
Market price	-4.01	4.01	0.0

Ex-ante risk measure
(measured at time 0)

Ex-post risk measures
(measured at time 1)

Disaggregating risk measures

- Each of the risk measures – including the market price measure – can be disaggregated by source
  - So you can analyse the total exposure to risk in terms of its constituent pieces
  - I assume you have covered the various methods of disaggregating VaR (Euler etc) in your risk management class
  - The market price of risk measure will not be additive
    - This is because hedging one source of risk affects your exposure to others if the risks are correlated and so affects the cost of eliminating the remaining exposure – if you can

Disadvantages of market price measure

- The market price measure is only useful if you want to know how much it will cost to hedge yourself against the risk
  - If you are interested in running the risk, then you need to use ex-post measures to see what the consequences will be for your company or pension fund
- The market price measure can only be used to measure the price of risks which are hedgeable
  - If a risk cannot be hedged, then obviously it cannot be priced

Changing the asset allocation

- This is the responsibility of the trustees
  - In the UK, up to 50% can be member-nominated
  - The remainder are appointed by the sponsor
- We will examine the following types of asset allocation
  - Equities vs. bonds
  - Types of bonds
  - Swaps
    - Interest rate and credit
  - Longevity bonds

Changing the asset allocation

- This changes the distribution of the likely cash flows and therefore alters their
  - expected value and variance
  - the likely incidence between employers and employees
  - the cost of the hedging portfolio
- As we discussed in the QCS, in this simple model, there is no optimum investment strategy from the point of view of the employees, and the employer would like the investment strategy to be as conservative as possible

Measures of risk (II)

	Employer	Employee	Total
Mean	-0.35	2.65	2.30
Std dev	7.1	3.7	10.4
95% VaR	-12.9	0.0	-12.9
99% VaR	-18.2	0.0	-18.2
Expected shortfall	-6.7	0.0	-6.7
Probability of shortfall	0.44	0.0	0.44
Market price	-2.01	2.01	0.0

- This shows the risk measures when the assets are 50% in equities and 50% invested in matched bonds
  - There is some sampling error (only 1000 runs)

Measures of risk (III)

	Employer	Employee	Total
Mean	0.0	0.0	0.0
Std dev	0.0	0.0	0.0
95% VaR	0.0	0.0	0.0
99% VaR	0.0	0.0	0.0
Expected shortfall	0.0	0.0	0.0
Probability of shortfall	0.0	0.0	0.0
Market price	0.0	0.0	0.0

- And this shows the different measures when we invest entirely in a position of matched bonds in our simple pension plan (there is no risk other than investment risk!)

Implications of higher equity investment

- Corporate implications
  - Higher leverage (but without the tax advantage)
  - Lower expected future pension contributions
  - Riskier future pension contributions
  - Increased possibility of sharing surplus with members
  - Higher value of default option if advance credit is taken for the ERP
- Member implications
  - Less secure benefits if advance credit is taken for the ERP
  - Higher possibility of sharing in surplus

Taking advance credit for ERP

- In normal accounting procedures, if risks are borne the rewards are only accounted for once they have been achieved
  - E.g. investing in a new project with a 50% chance of success and a profit of £1m per year if it is successful
    - Most companies would not book £500K of profits per year before it became clear whether the project was successful or not (and would not be permitted to)
- The same should be true of measures of pension funding

Taking advance credit for ERP

- When companies determine pension contributions discounting liabilities at an equity rate, then this is effectively exactly what they are doing
- Let's look at our risk measures if the company in our stylised pension plan only contributes 96 to the plan (so the future expected value of the surplus is 0), and invests the entire pension plan in equities

Taking advance credit for ERP

	Employer	Employee	Total
Mean	-4.42	4.20	-0.22
Std dev	15.6	6.8	21.4
95% VaR	-31.8	0.0	-31.8
99% VaR	-41.3	0.0	-41.3
Expected shortfall	-15.9	0.0	-15.9
Probability of shortfall	0.54	0.0	0.54
Market price	-3.01	3.01	0.0

- We are not modelling default risk here, so here the change does not expose employees to default risk (which it will do in practice, thereby reducing the value of their claim)
  - But it does reduce the value of employee's claims by reducing the possibility of shared surplus
  - And it increases the risk the employer is running

Key issues in bond investment

- Asset – liability matching
  - Differences between the term and nature of the assets and the liabilities expose the sponsor (and members) to interest rate and inflation risk
  - May need dynamic hedging to hedge some of the liability risks
- “Accounting” vs “economic” liabilities
  - There is a difference between the measure of liabilities reported in the accounts and the true economic measure of the liabilities

Accounting vs economic liabilities

- The accounting liability is the liability that will be in the accounts
  - Under FRS17 it depends on AA bond spreads, and so is best hedged with a mix of bonds that reflects the index that is used to determine the discount rate
- The economic liability is the “true” liability
  - Best hedged by holding a portfolio of bonds which matches the timing and nature of the cash flows themselves

Types of (bond) asset-liability matching

- Redington immunisation
  - Duration matching
- Multi-period immunisation
- Cash-flow matching
- Horizon matching
- LDI

Redington immunisation

- Frank Redington was actuary of the Prudential in the 1950's
- The percentage change in the price of a bond when interest rates change is given by the formula:

$$\frac{\Delta P}{P} = -D\Delta r + \tfrac{1}{2}C(\Delta r)^2$$

Percentage change in price of bond

Duration of bond (years)

Change in interest rates

Convexity of bond

- This is (just) a second-order Taylor expansion in the price

Redington immunisation

- Therefore, if your assets and liabilities have the same duration, but the assets are more convex, then:
  - Assets will increase more when there is a parallel shift in the yield curve than liabilities will
  - And so your surplus will always increase if there are parallel shifts in the yield curve
- What does this mean about parallel shifts in the yield curve?

Immunisation risk

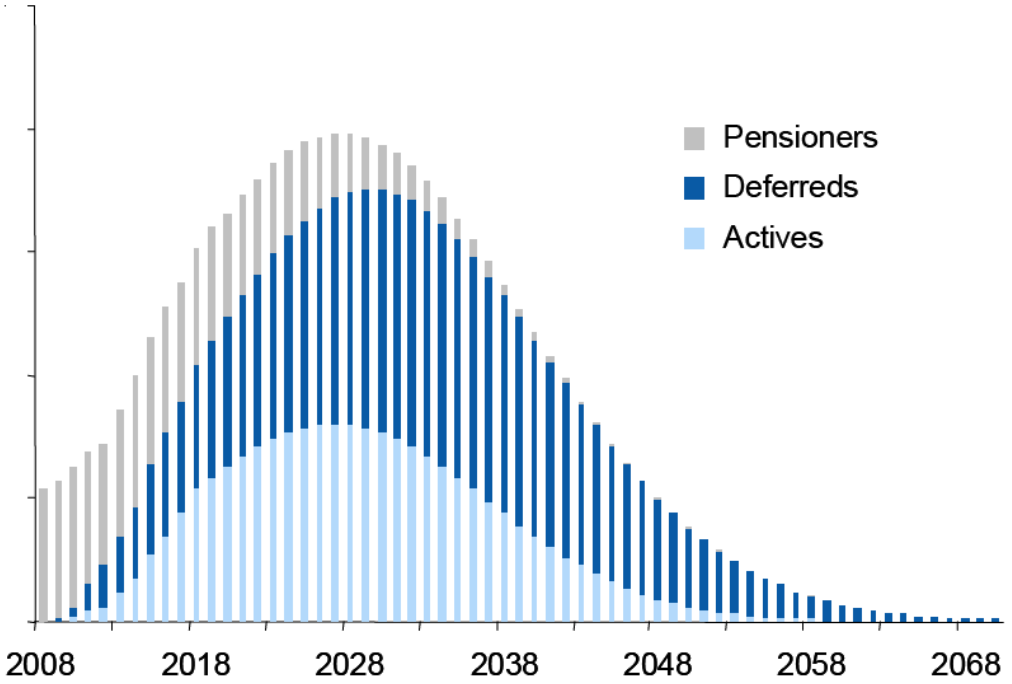
- This is the risk which immunisation exposes you to if there are not parallel shifts in the yield curve
  - Then the asset and liability portfolios will not respond in the same way and the surplus may actually decrease if the yield curve shifts
- Risk implicit in rebalancing
  - If interest rates change a lot, then the portfolio will have to be rebalanced because the durations will have changed (precisely because of differing convexities between asset and liability portfolios)
  - With the passage of time there will need to be rebalancing

Multi-period immunisation

- Pension funds face a variety of cash flows
  - Each payment will need to be immunised individually, which is complex and a little self-defeating, when you can just cash-flow match each individual payment
  - This is called cash-flow matching

Cash flow matching

- Find the lowest-cost portfolio which matches the pattern of expected liability payments
- You can do this by buying a bond with the longest maturity duration first, and then successively calculating earlier durations, taking into account the coupons of the later-maturing bonds



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- Can be difficult if the nature (i.e. inflation exposure) of the liabilities is matched as well as the amount of the cash flows

Horizon matching

- This matches only the cash flows up to a specific horizon, and beyond that the liabilities are immunised rather than matched exactly
- Saves expenses but may expose fund to greater risks
- For some funds with high proportions of active members, this may be the only alternative as very long-dated swaps are not available

Liability-driven investing

- This tries to secure the expected liability cash flows at lowest risk to the sponsor
  - Matches the following sources of risk exactly
    - Interest rate
    - Inflation
    - Longevity
    - Credit risk of sponsor
    - Wage risk

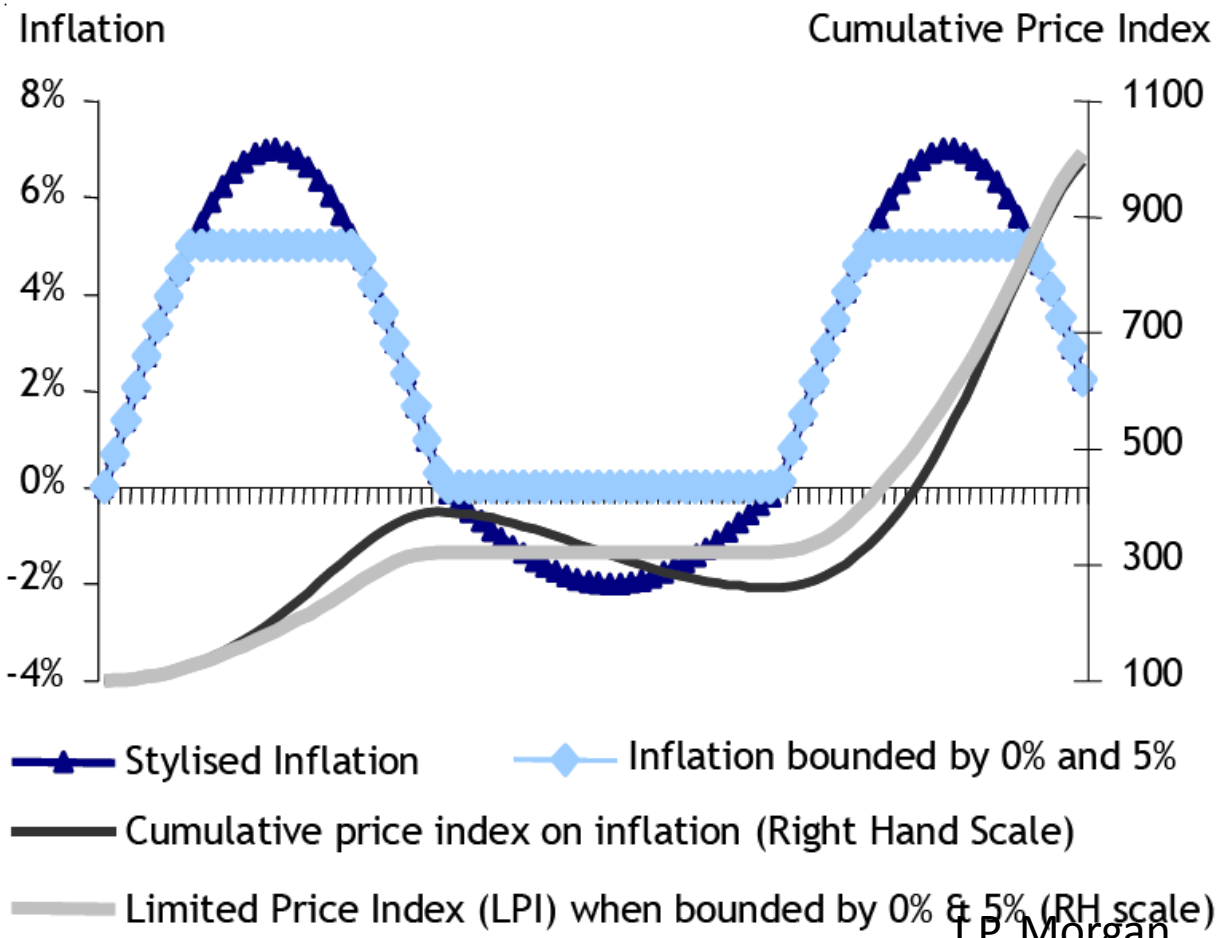
Can be well hedged using investments that exist already (e.g. real and nominal swaps, LPI bonds or portfolios etc)

Require longevity bonds or credit default swaps, which may only be thinly traded, if at all

Instruments don't really exist yet

Pension fund inflation exposure

- LPI 2.5%, 3%, 5% in payment
- LPI 5% in deferment
- (all p.a.)
- (Not economically well justified, but rather risk-sharing between sponsor and members by diktat)



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Swaps

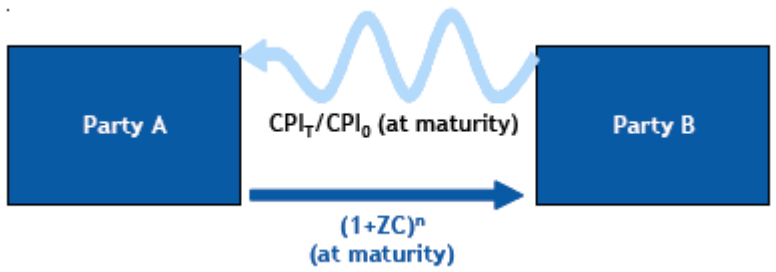
- These are a type of financial instrument where parties agree to swap payments on different financial instruments
  - In principle, can be linked to anything, such as mortality, credit worthiness, inflation and interest rates
  - In practice, mortality swaps are not yet actively traded, but interest rate and inflation swaps and credit default swaps are traded (for large companies)

Swaps

- This is where one institution swaps payments with another institution on an agreed basis
  - E.g. an institution agrees with a bank to pay the bank LIBOR on a notional principal of £10m, and in exchange receives fixed payments of 4.5% p.a. on the notional principal for 10 years
    - The institution is long the fixed leg of a fixed-floating swap
- The payments can be based on any underlying index or security, such as interest rates, inflation rates, exchange rates, mortality indices, equities etc.
- Pricing is consistent with no arbitrage

Zero-coupon swaps

- All payments happen at maturity
- Purchaser receives (eg) inflation / LPI etc, but pays a fixed rate (determined at the outset, which is effectively the price of the swap)
- Collateralisation important



Party A:	[ ]
Party B:	[ ]
Start Date:	01-FEBRUARY-08
Maturity Date:	01-FEBRUARY-18
Notional Amount:	€ xxx M
Floating reference:	Euro HICP Ex Tobacco unrevised (2005 = 100) as published by Eurostat (as found on Bloomberg CPTFEMU Index)
$Index_0$:	Euro HICP NOVEMBER 2007
$Index_T$:	The Euro HICP index unrevised 3 months prior to the Maturity Date
Payment Date:	01-FEBRUARY-18 subject to modified business day convention.
Party A Pays:	Notional Amount $\times$ (1 + BEI)^T where T is the number of full years between Start Date and Maturity Date
Party B Pays:	Notional Amount $\times$ ($Index_T$ / $Index_0$)

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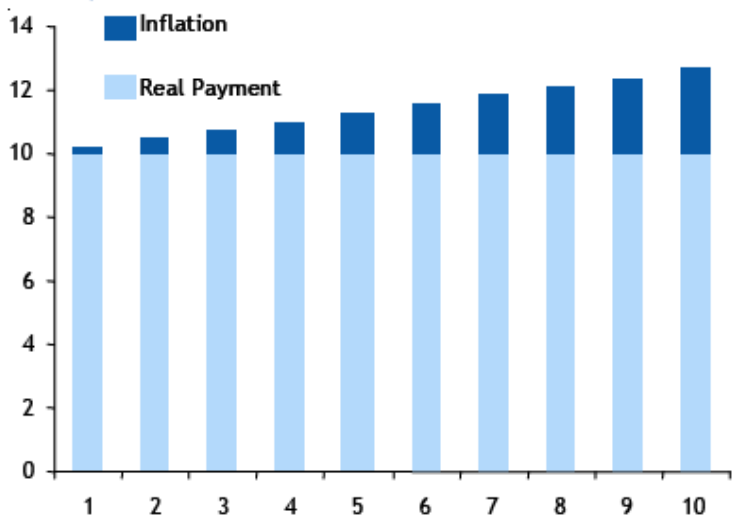
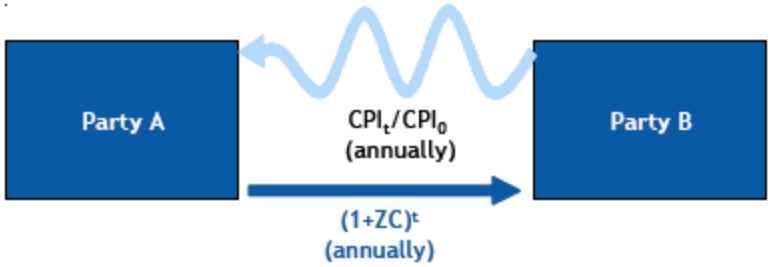
Inflation annuity swaps

- Useful in hedging out inflation exposure on annuities in payment (so great for pension funds)
- Can be though of as a portfolio of zero-coupon swaps





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Party A Pays:	Notional Amount × (1 + BEI)^t where t is the number of full years between Start Date and Payment Date
Party B Pays:	Notional Amount × ($Index_t$ / $Index_0$)

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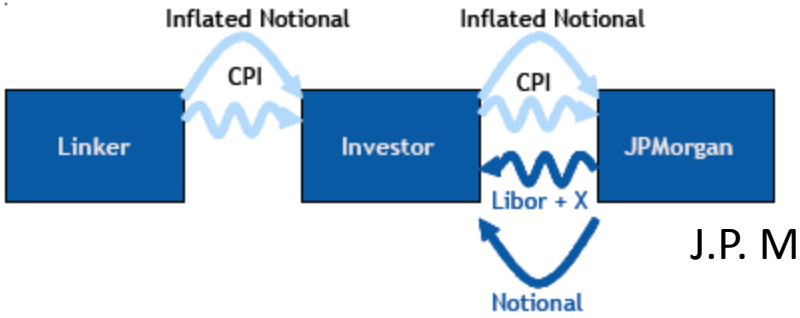
Asset swaps

- These can be used to “transform” one asset into another
- For instance, a pension fund has a portfolio of nominal gilts, but wishes to increase its exposure to index-linked gilts
- It can then enter into an asset swap, where it:
  - Receives the coupons on its own portfolio;
  - Uses these to make the fixed leg payment under the swap agreement; and
  - Receives the inflation-linked payment under the swap agreement, so its fixed assets have been “converted” into index-linked ones

Asset swaps

- Can also do these if you hold linkers (inflation indexed bonds)



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- Three kinds
  - Par-par (where there are balancing capital payments at time zero between par and the dirty price of the bond)
  - Proceeds-based (where the swap is transacted on the dirty price of the bond)
  - Z-spread

Counterparty risk and swaps

- Swaps are transacted with a counterparty, not through a clearing house
  - Counterparty is typically a large bank, which either nets off cash flows or uses repos to generate exposure
  - Collateralisation arrangements are very important
    - Quality and frequency
  - Termination agreements specifying termination event and calculation of loss can be important and should be scrutinised
  - Responsibility of principals vs asset managers (especially in segregated portfolios)

Swaps typically use (3 or 6-month) LIBOR

- Use of LIBOR as the reference for swaps
  - LIBOR is not a tradable rate
  - LIBOR includes a spread for credit risk of banks (this became extreme at various points during the credit crisis)
  - Pension funds with swap agreements in place need to generate LIBOR on their assets, which is impossible without taking credit risk
    - "enhanced" cash strategies could do this (more on the next slide)
    - asset swaps / some kind of collateralised lending to banks are possibilities (may have to accept LIBOR minus)

Funds with swap overlays (can) invest in cash…

- Cash funds
  - Tend to invest in short-dated credit (Floating Rate Notes) to generate LIBOR target
  - Heavily exposed to financial sector so heavily affected by crisis
  - As credit spreads came up, these notes were revalued and fell in value
    - Provided defaults didn't occur, the money was made up as the FRN's matured

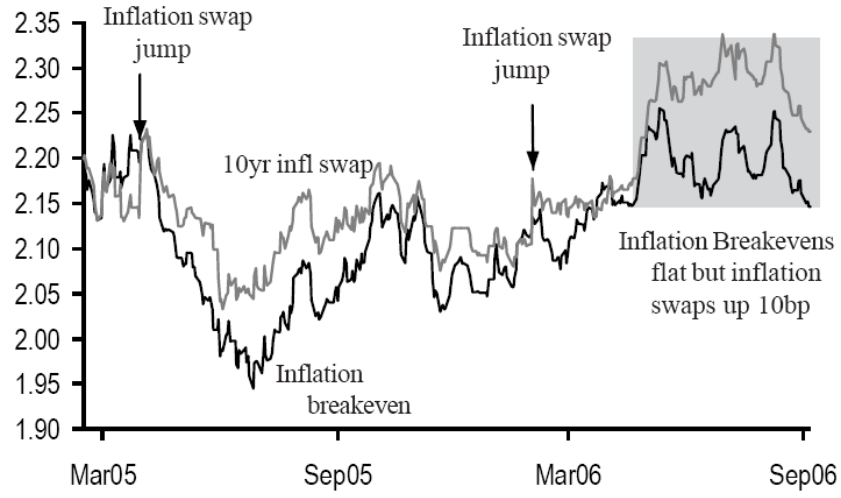
… or not? (geared swap overlays)

- You can buy a swap which has a notional greater than the amount of assets that you have in the fund
  - This is called a “geared” swap overlay
  - You might do this to obtain full inflation exposure even when the scheme is underfunded
  - This effectively increases the target rate of return that is required on the underlying assets to meet the payments due under the swap agreement
- Or fund can invest in equities and mismatch
- But then the sponsor (or pension insurer, or members) take in mismatch risk

Swaps and bond breakeven inflation don't move in tandem

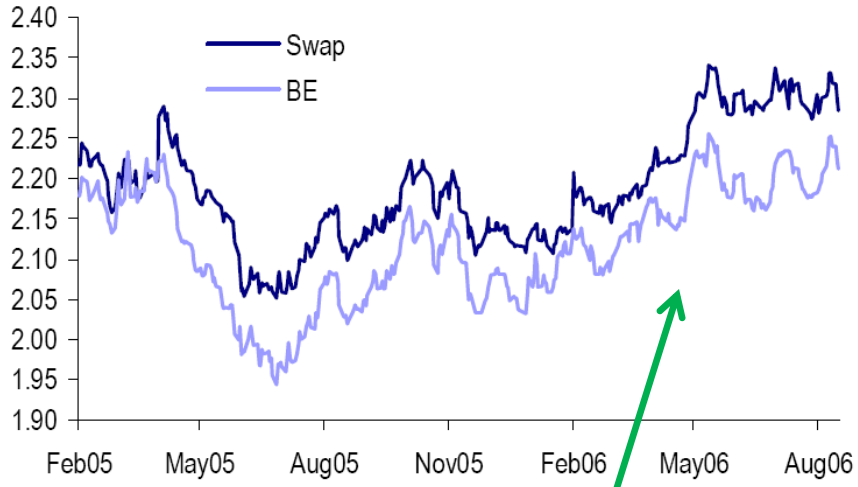
- Both represent measures of inflation expectations plus term premia for inflation
- But breakeven inflation rates reflect CPI seasonality

Inflation breakeven OATei 2015 vs 10-year inflation swap EuroHICPxt (zc)



Source: JPMorgan

Inflation B/E OATei 2015 vs equivalent inflation swap (rolling start date)



Source: JPMorgan

Inflation swap corresponds closely with period of bond break-even inflation

Hedging exposure to mortality

- Overall, the market is way short longevity exposure
  - Governments and DB pension funds are very short longevity (i.e. payments increase if longevity improves)
- There are a number of options to hedging mortality
  - Reinsurance
  - Capital market instruments
    - Mortality swaps / q-forwards
    - Longevity bonds

Potential longevity risk buyers and sellers

Potential longevity buyers		Potential longevity sellers
■ Over $8tr liabilities exposed to longevity (US, UK) ■ Current tables likely to underestimate risk ■ Beginning to evaluate impact of this risk	Pension Funds	
■ Exposed to longevity risk through annuity policies ■ Would look to hedge exposure	Annuity Providers	■ Could write protection to synthetically gain exposure to risk ■ Have the sophistication to analyse risk/return
	Life Insurance Companies	■ Exposed to declines in longevity through life insurance policies ■ Selling longevity offsets this risk
■ Exposed to longevity risk through investment portfolio ■ Buy protection to hedge general trend risk	Life Settlement / Premium Finance Investor	■ Sell longevity and earn premium ■ Can use existing expertise to evaluate risk/return
■ Buy protection against longevity risks from plan acquisition	Pension Buyout Funds	■ Can use existing expertise to evaluate risk/return ■ May synthetically add exposure
	ILS Investors	■ Provide protection and earn premium
	Other Hedge Funds	■ Have liquidity and seeking return
	Endowments	■ Have liquidity and ability to "buy & hold" ■ Long term investors ■ Innovators
	Pharma	■ Could issue debt ■ Naturally exposed to declines in longevity
	Others (e.g. Reverse mortgage, healthcare)	

Source: JP Morgan

Issues in developing a mortality market

- Liquidity vs basis risk
- Supply-demand balance
- Objectivity
- Transparency

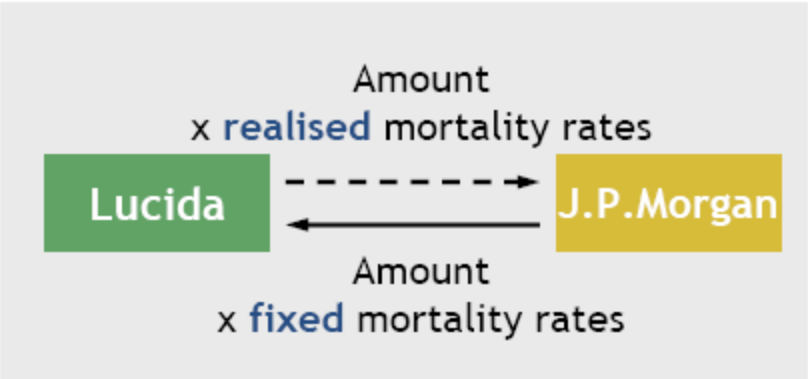
Possible developments

- Mortality bonds
  - Based on survival (so path dependent)
    - Kills liquidity
  - No settlement of mortality beyond term of bond
    - Restricts usefulness as a hedge
- Life expectancy can't be used either
  - Not known until last person does and so always an expectation
- q-forwards
  - Mortality swap based on an anticipated value of probability of death in a few years (e.g. US 70-74 y/o males in 2018)

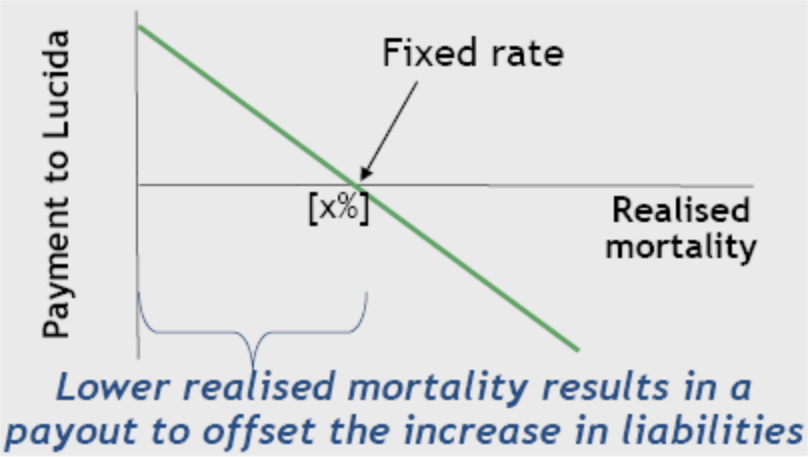
q-forwards

- Lucida (a buy-out company) has already transacted a q-forward with J.P. Morgan
- Like a regular swap contract
  - If realised mortality is above the reference level, then the purchaser makes a payment to JP Morgan, otherwise vice-versa
- (In this case) transaction was fully collateralised

q-Forward: Index-based longevity hedge



Payout from q-Forward



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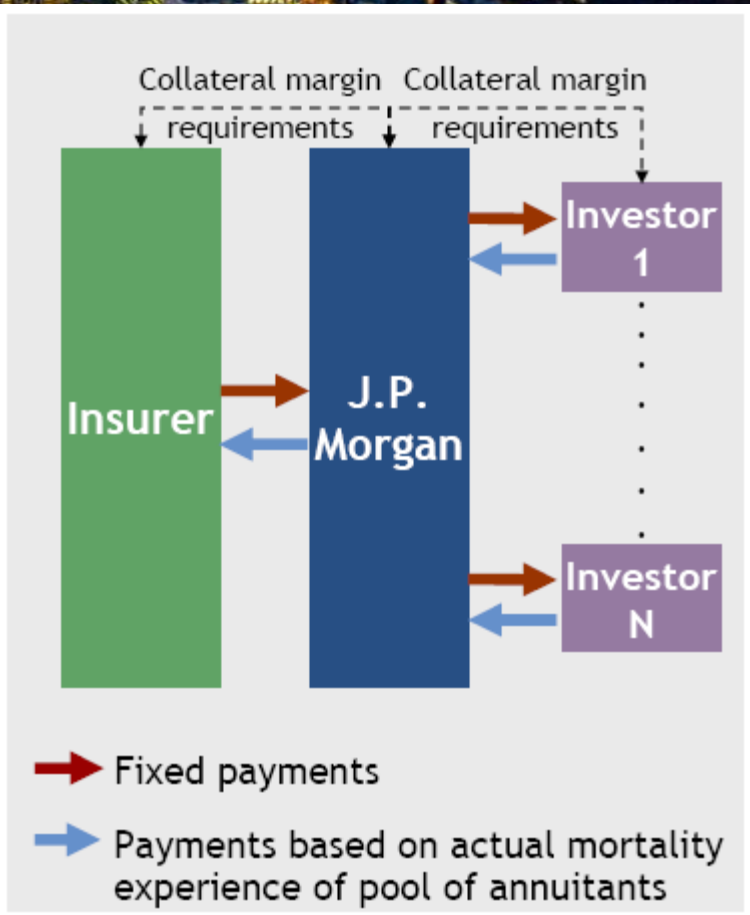
Investment bank can pass on the exposure to third parties

- In a second transaction, JP Morgan wrote a £500m swap with a large life insurer
- Simultaneously passed on the risk through mirrored swaps to a number of large capital market investors
- Effectively JP Morgan is an intermediary, bringing the two parties together



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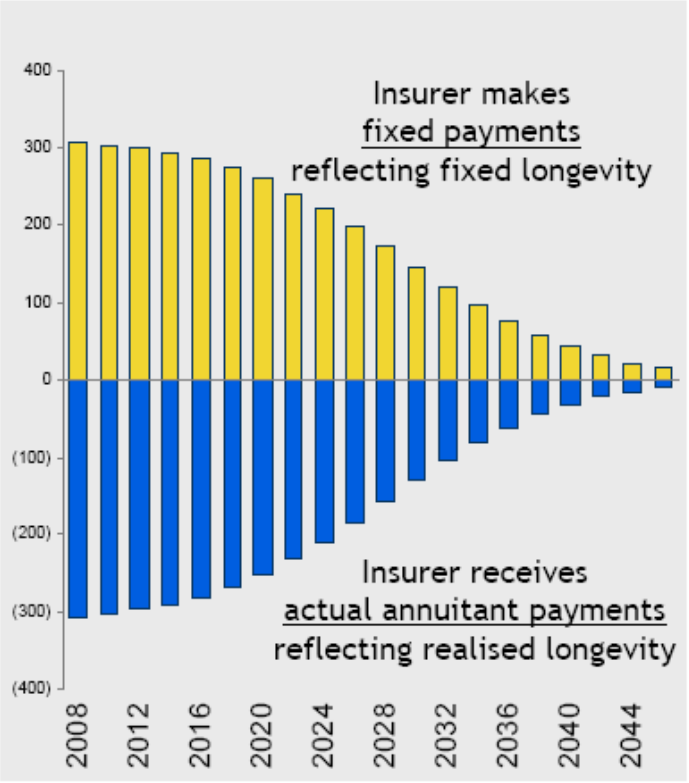
Annuity longevity swap

- Investor would expect to be rewarded for taking on the risk
  - In the form of a risk premium
  - So what would the expected value of the swap transactions be?
  - How to calculate the risk premium that would be appropriate?
    - Liquidity risk
    - Variability of mortality risk
    - Risk aversion of investor
    - Extent of diversification
    - Time horizon / counterparty risk

Longevity cash flow swap payments



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Broad issues in investment strategies

- Liquidity
- Counterparty or default risk
- Correlation
- Tax
- Dealing expenses
- Currency risk
- Nature
- Tenor

Recap

- You have built a model which predicts cash flows to the different parties conditional on the outcome of various state variables
- You have decided on a risk measure, and a party that you are advising
- You then change the asset allocation – including potential allocation to assets such as swaps and q-forwards – to meet the goals of the stakeholder
- You analyse the risks of your model and the risks that are not accounted for in your model and advise the stakeholder about those, too

Changing sponsor's financial structure

- One risk management option is to change the financial structure of the sponsor
  - For example, you could advise the sponsor to borrow money and invest this in the pension plan
    - This would reduce pension plan risk and may increase the sponsor's value
  - (Or the sponsor could just make contributions to the pension plan)

Pension deficits vs formal leverage

- Pension deficits are a form of leverage
  - So the discussion fits within the broader framework of a company's optimal leverage structure
    - Tenor / nature / type of instrument
- Miller-Modigliani says that if there is an optimal capital structure then it must be the result of some identified capital market inefficiency

Subtle changes in capital structure

- Dynamic contribution strategies are simply a change in capital structure of company, but which are hidden in the accounts
  - E.g. an agreement by the company to contribute more if investments do badly
  - This is effectively a swap, but on-balance sheet
  - In principle, it is identical to a certain investment strategy in the pension fund, once the issues of default risk and irrecoverable surplus are ignored

‘Liability management’

- There are several ways companies can manage their pension liabilities
- Past liabilities can be bought out if enough members agree to sell their rights, but can be legally difficult
- Discretionary benefits can be amended (subject to PRE)
- Plan can be:
  - Changed (e.g. career average instead of final salary)
  - Closed to new entrants
  - Frozen, so existing members don’t accrue new service, or
  - Wound up

Discontinuance

- Benefits may be affected by:
  - Rights of beneficiaries
  - Expectations of beneficiaries
  - Method of provision of future benefit payments
  - Level of assets available

Method of provision

- Scheme continues without sponsor
- Transfer to another scheme with same sponsor
- Transfer of funds to beneficiary
- Transfer of funds to insurance company / buy-out provider
- Transfer of funds to central discontinuance fund
- All subject to national law and trust law (in the UK)

Level of assets

- If assets are not sufficient, then:
  - Sponsor may be called on to pay difference;
  - Benefits are to be reduced (which benefits, and how, depends on national law); or
  - Insurer may pay

Reinsurance / securitisation / buyout

- Reinsurance might be useful for a pension fund trying to reduce the random volatility of its outflow
  - Remember the liability profile is just the expected value; even if mortality decreases in line with forecasts, the scheme will have additional variation over and above that, especially if it is small
  - It may offer a proportional or excess-of-loss contract
- Or funds may simply purchase annuities or deferred annuities
- Counter-party risk, size of risk premium, ancillary services need to be factored into decision

Securitisation

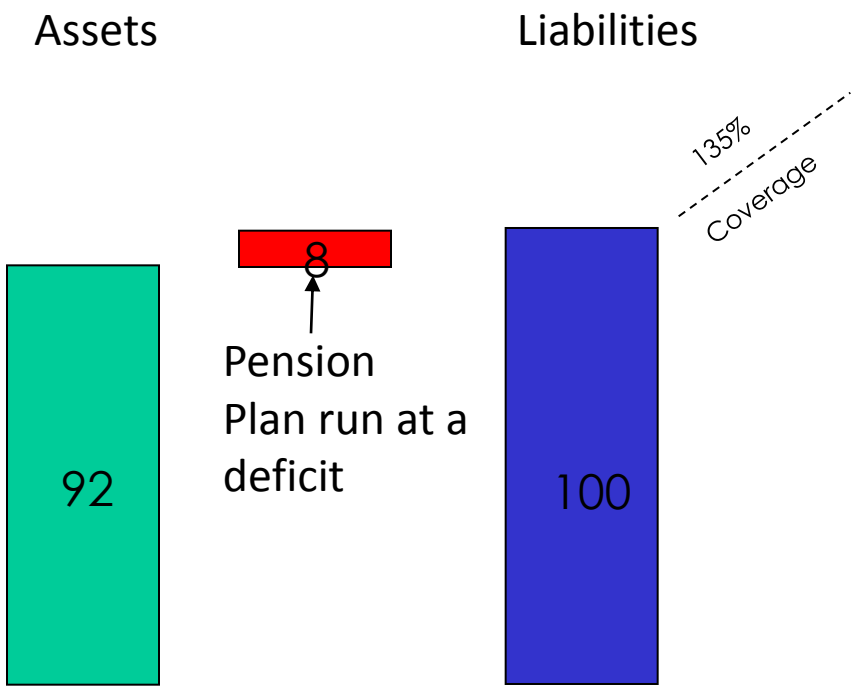
- UK securitisation markets are currently not functioning normally
  - In principle, a pension fund could construct a mortality securitisation deal which would give it protection against catastrophic mortality outcomes, as, for instance, the Swiss-Re Vita life deal
  - No pension fund has done this, to my knowledge

Pension buy-out

- There are companies that will buy out the entire DB pension liabilities of companies
- Prices are apparently currently at all-time lows as there are many new entrants to the market
- As we have discussed, the price is higher than the ongoing liability valuation (because these take credit for future asset returns, and because there are allowances for risk premiums in the insurance company valuation)
- You could put these into the cash flow model you have derived and evaluate the pros and cons of buy-out.
- Partial buyouts are also possible.

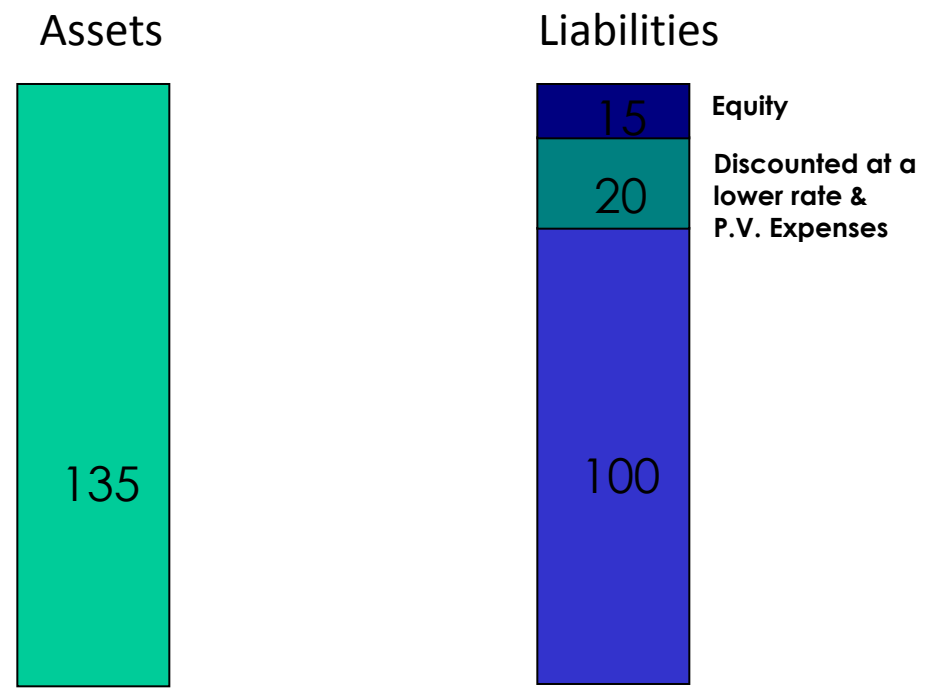
Pension fund versus insurance

Pension Plan



- Plus Corporate Covenant
- Plus PPF

Insured Pension



- Risk in the Asset Portfolio is generally lower due to Regulatory Constraints
- Plus FSA Compensation Scheme

Source: David Collinson

Lecture summary

- We examined these four methods of managing pension risk:
  - Changing the asset allocation of the scheme
  - Changing sponsor financial structure
    - i.e. fund the scheme, change firm leverage, provide contingent assets etc.
  - Liability management
  - Reinsurance / securitisation / buyout
- Remember model risk!!!