# *Defined Contribution (DC) Pension plans: The Impact of Financial Risk on Individuals and on Population Dynamics*

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## Outline for talk

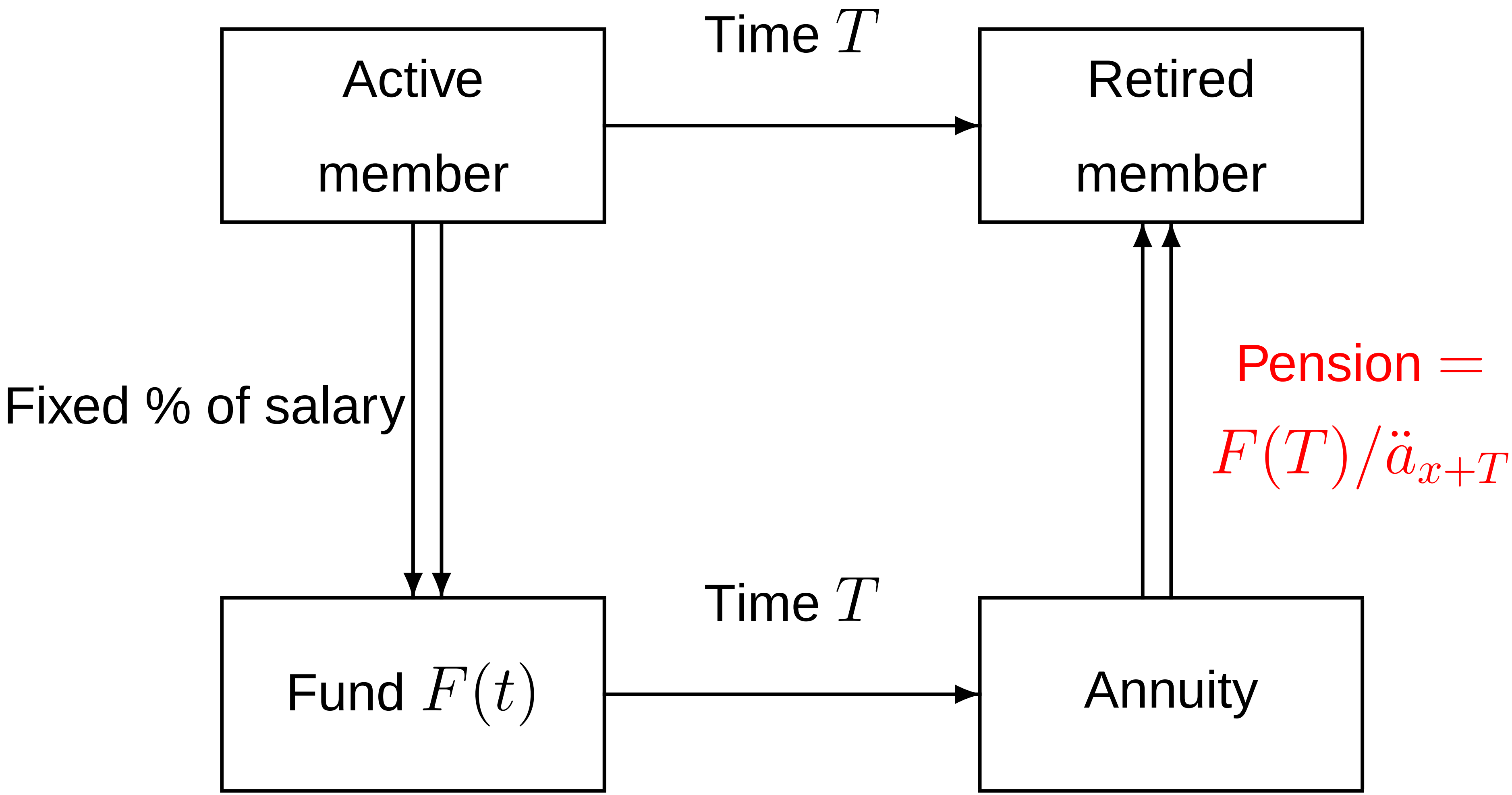
- Overview: Accumulation phase of a DC plan
- Fixed retirement age
  - Risk assessment
  - Comparison of optimal strategy with commercial strategies
- Flexible retirement age
  - Implications for individual members
  - Implications for population dynamics

## Accumulation phase

## Motivation

- DC plans now as important as DB plans
- DC $\Rightarrow$ Financial risk borne by individual members
- Perceived need for research to help members
  - assess the risks
  - manage the risks

Time 0: Age $x$


Time $T$
Active member
Retired member
Fixed % of salary
Pension $=$ $F(T)/\ddot{a}_{x+T}$
Time $T$
Fund $F(t)$
Annuity

## Control variable: Investment strategy

- various asset classes
- choice of “commercial” investment strategies
- static versus dynamic

For a given investment strategy:

How well does a DC plan match a DB benchmark?

$$\text{Pension Ratio} = \frac{\text{DC pension}}{2/3 \text{ final salary}}$$

# Typical *default* strategies

## Static strategies

- Pension Fund Average (PFA)

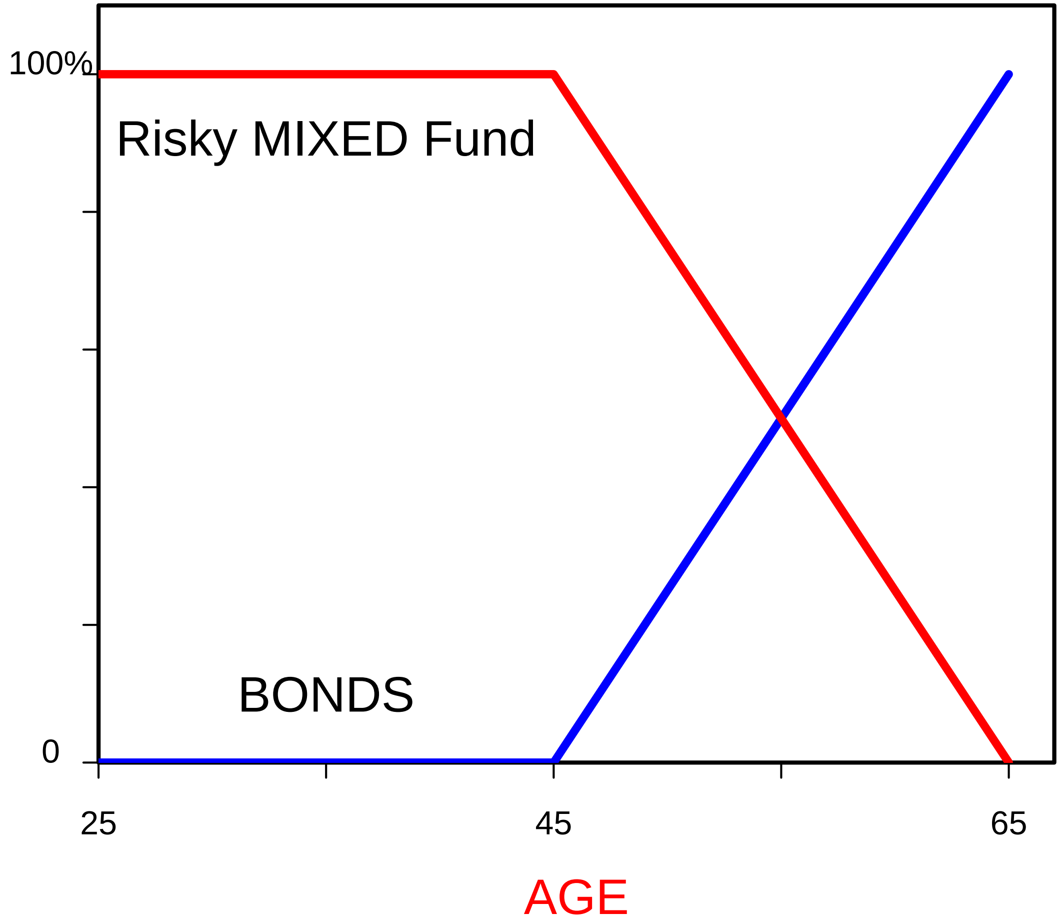
  typical mixed fund ($\sim$ 70% in UK/int'l equities)

- Mixed Bonds (50/50)

  50% long bonds;   50% cash

  $\Rightarrow$ minimum variance of Pension Ratio

# Deterministic Lifestyle strategy




Initially MIXED fund. Then switch gradually into BONDS.

## Default “commercial” strategies:

- Static
- Deterministic lifestyle
- Portfolio insurance (CPPI)
- Threshold strategy

Are these strategies the best that we can do?

By how much can they be improved?

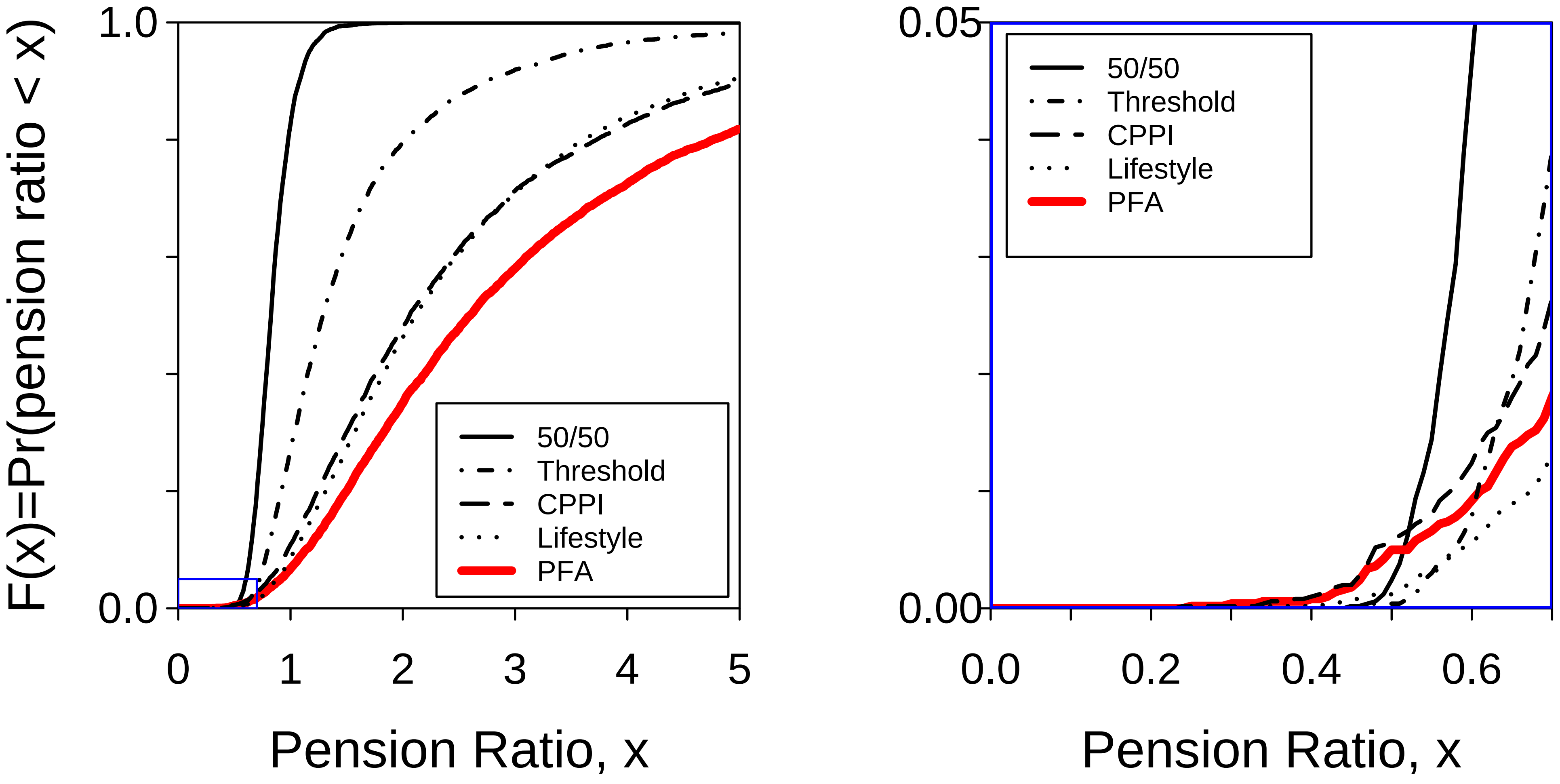
- theoretical best
- practical best (not this talk!)

# Example: Fixed retirement age

- Member enters at 25, retires at 65
- Contribution rate: 10% of salary
- Accumulated fund used to buy level annuity
- Various investment strategies considered

# Typical results (various asset models considered)

## Different investment strategies



# How to set the contribution rate?

- Median as a proxy for deterministic projection

  What % contribution rate

  $\Rightarrow$ 50% chance that pension ratio $> 1$

- What % contribution rate

  $\Rightarrow$ 95% chance that pension ratio $> 1$

50% chance that Pension Ratio $> 1$

| | Required C.R. (%) |
|---|---|
| PFA | 3.80 |
| Lifestyle | 4.69 |
| CPPI | 4.76 |
| Threshold | 7.69 |
| 50/50 Bonds | 11.90 |

“Low risk strategy” requires 3$\times$ PFA

# 95% chance that Pension Ratio $> 1$

| | Required C.R. (%) | |
|---|---|---|
| | 95% chance | 50% chance |
| PFA | 10.53 | 3.80 |
| Lifestyle | 11.11 | 4.69 |
| CPPI | 12.05 | 4.76 |
| Threshold | 13.51 | 7.69 |
| 50/50 Bonds | 16.39 | 11.90 |

## Accumulation stage: Initial conclusions

- CDF's all have a wide spread

  $\Rightarrow$ Degree of uncetainty is very high

- Regulators must be persuaded to allow, promote or even require stochastic projections

- Commercial investment strategies don't give substantially different CDF's from simpler static strategies

## We have looked at various “commercial” strategies:

- Static
- Deterministic lifestyle
- Threshold / CPPI

Are these strategies the best that we can do?

## Three questions:

1. How can we measure the success of a particular strategy?

2. What is the optimal asset-allocation strategy *ex ante*?

3. How do the commercial strategies compare with the optimal?

How can we measure the success of a particular strategy?

Retirement at fixed date $T$

Various possibilities:

we use plan member's utility function

$$
\begin{aligned}
\text{utility} &= f(\text{pension ratio at } T) \\
&= f\left(\frac{\text{DC fund}(T) \ / \ \text{annuity price}(T)}{\frac{2}{3}\text{Final salary}(T)}\right)
\end{aligned}
$$

Aim:

To find the asset-allocation strategy that optimises the expected utility.

Optimal strategy:

- may be dynamic
- may depend on past performance of investments
- may depend on current level of interest rates
- may depend on current level of salary

Popular choice: power utility

$$\text{utility} = \frac{1}{1-RRA}\Big(\text{pension ratio at } T\Big)^{1-RRA}$$

$RRA =$ relative risk aversion

What is new here:

- utility $=$ function of pension ratio

  rather than wealth

- continuous stream of premiums: $k\times$ current salary

## Modelling

Very simple model $\Rightarrow$

- stochastic asset returns, interest rates
- stochastic salaries; possibly non-hedgeable risk
- possible to find the “true” optimal strategy
- easy to compare with popular commercial strategies

$\Rightarrow$ clear qualitative conclusions about how good commercial strategies really are.

Model $\Rightarrow$ many assets

Optimisation $\Rightarrow$ we require only 3 mutual funds

A Minumum risk fund to match salary risk

mainly cash

B Minimum risk fund to match salary $\times$ annuity risk

mainly bonds

C Efficient, risky fund

A, B, C adjusted for correl. between salary and assets

## Complete market:

## Main conclusions: optimal strategy

- Effective assets at $t$ are

$$\overline{W}(t) = \text{actual pension wealth, } W(t) + \text{risk-adjusted value of future premiums, } RAVFP$$

Borrow $RAVFP$ in units of mutual fund A

## Main conclusions: optimal strategy

- Investment in risky fund C

  $= $ constant % of $\overline{W}(t)$

  constant % depends upon plan member's relative risk aversion, $RRA$

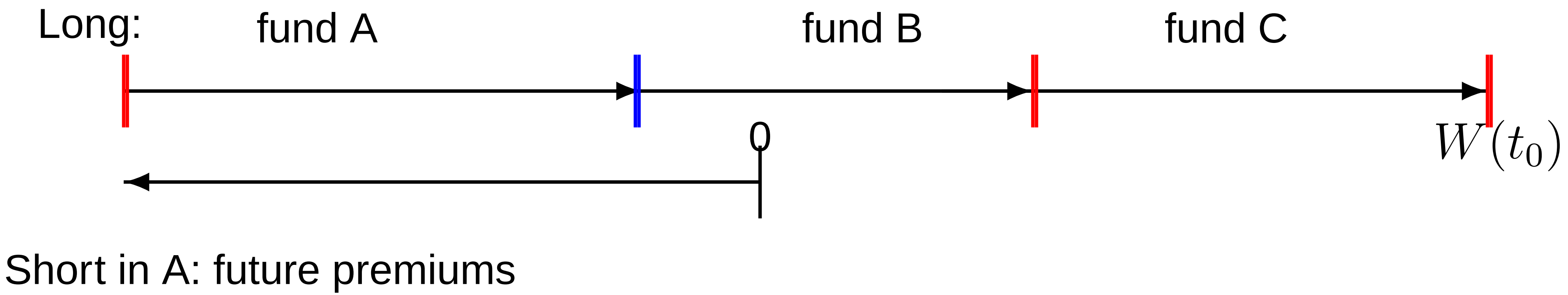
- *As a percentage of* $\overline{W}(t)$

  investment in mutual fund B grows over time

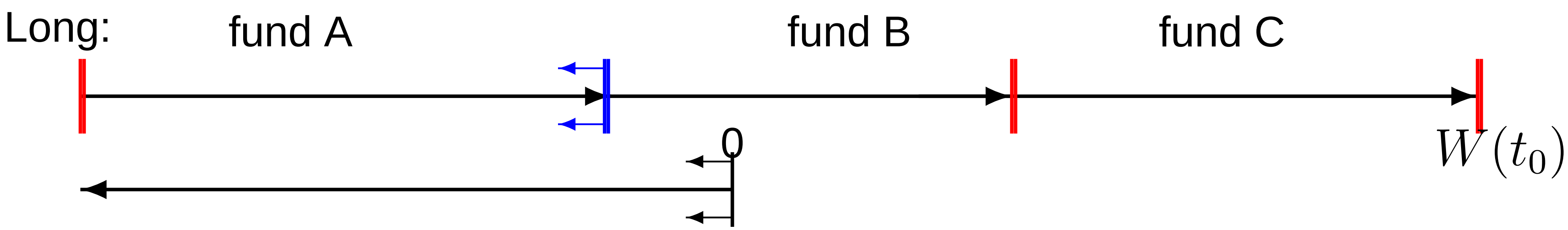
  investment in mutual fund A falls

# Investment in Mutual Funds A, B, C:

small $t_0$, some wealth, $W(t_0)$, accumulated

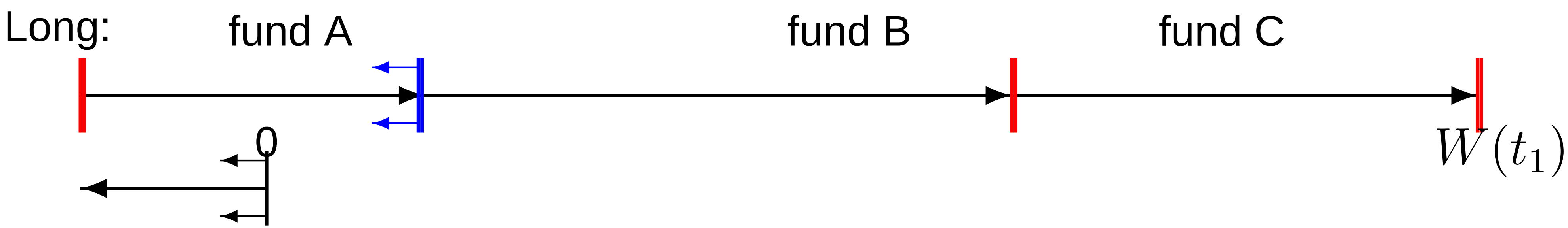


Small $t_0$ (as before)




Short in A: future premiums

Large $t_1$

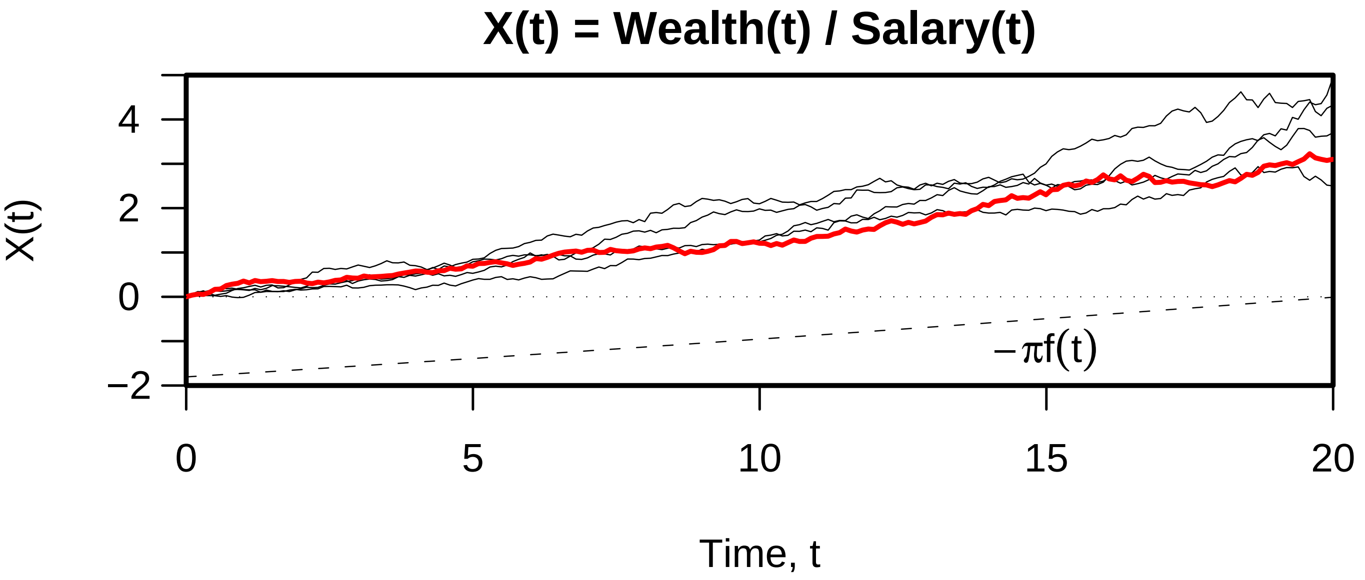


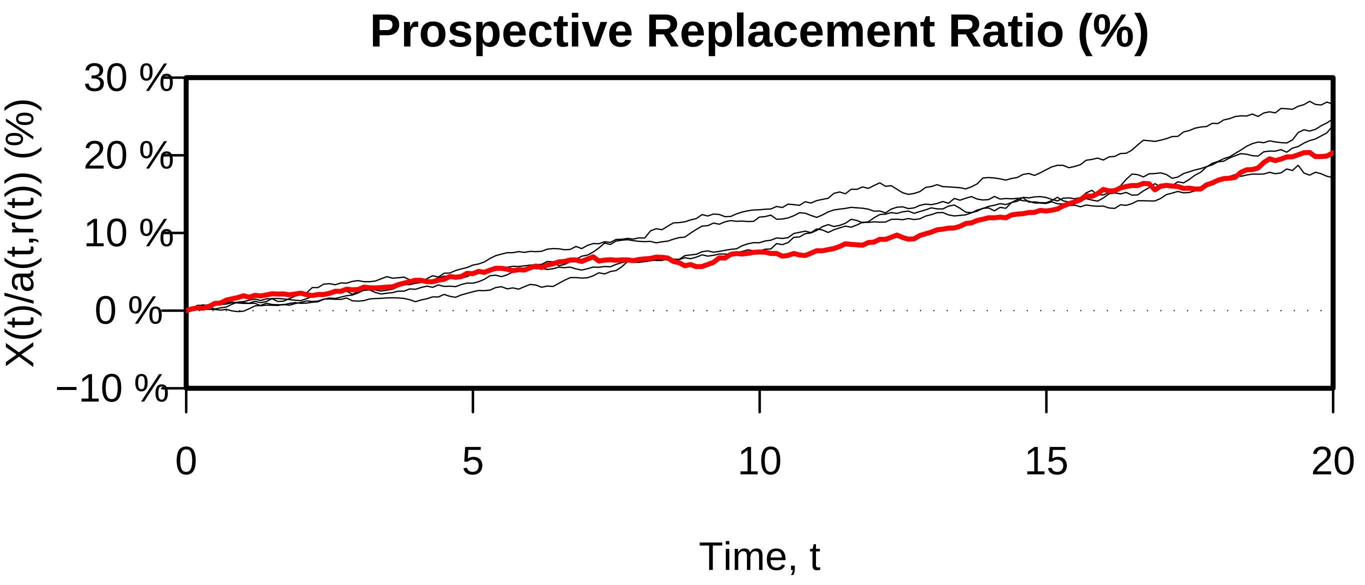

Short in A: future premiums

## Example 1:

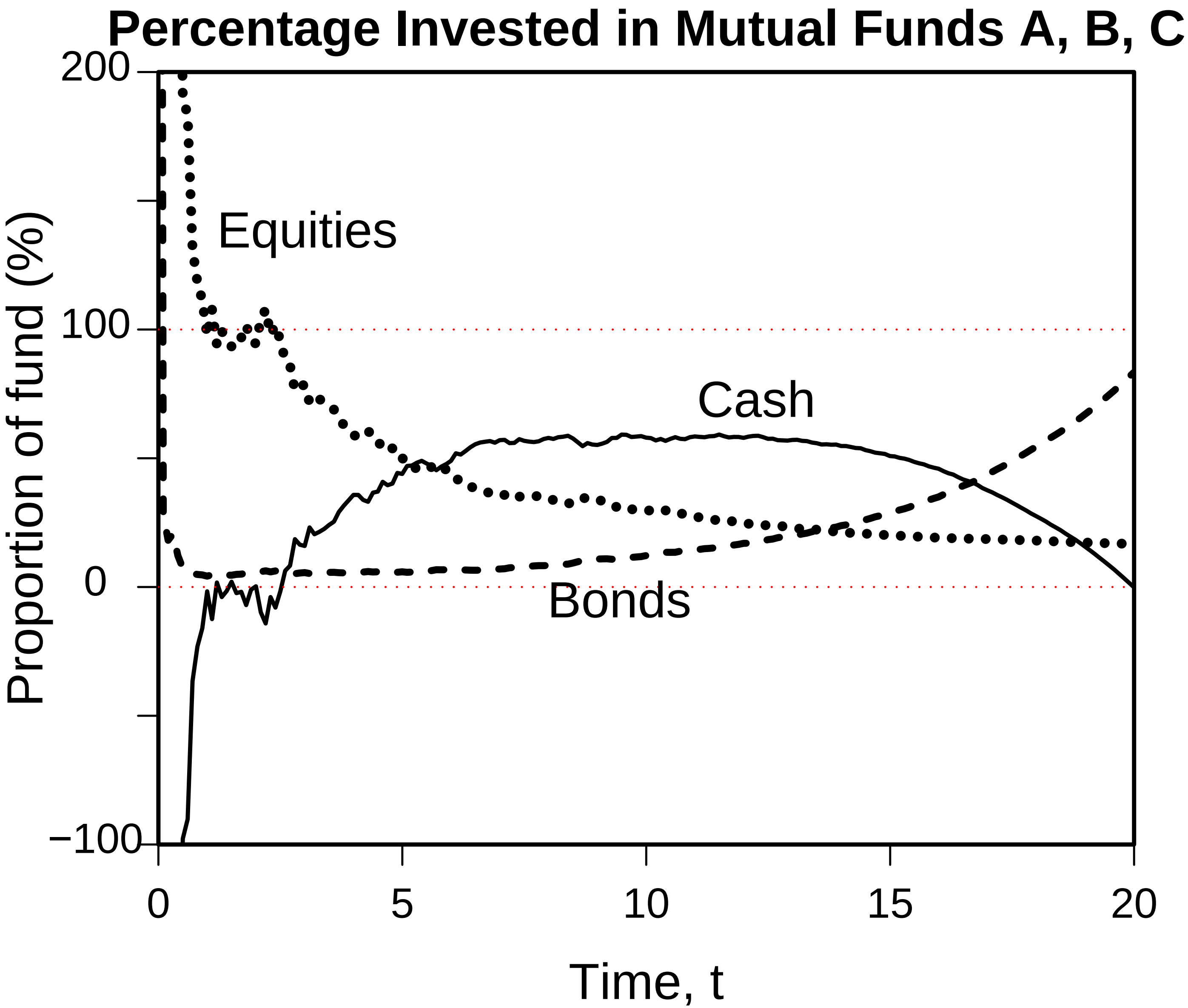
- Relative risk aversion: $RRA = 6$ (moderate)
- Duration of contract: $T = 20$ years
- Contribution rate: 10% of salary

# Example 1: $RRA = 6, T = 20$

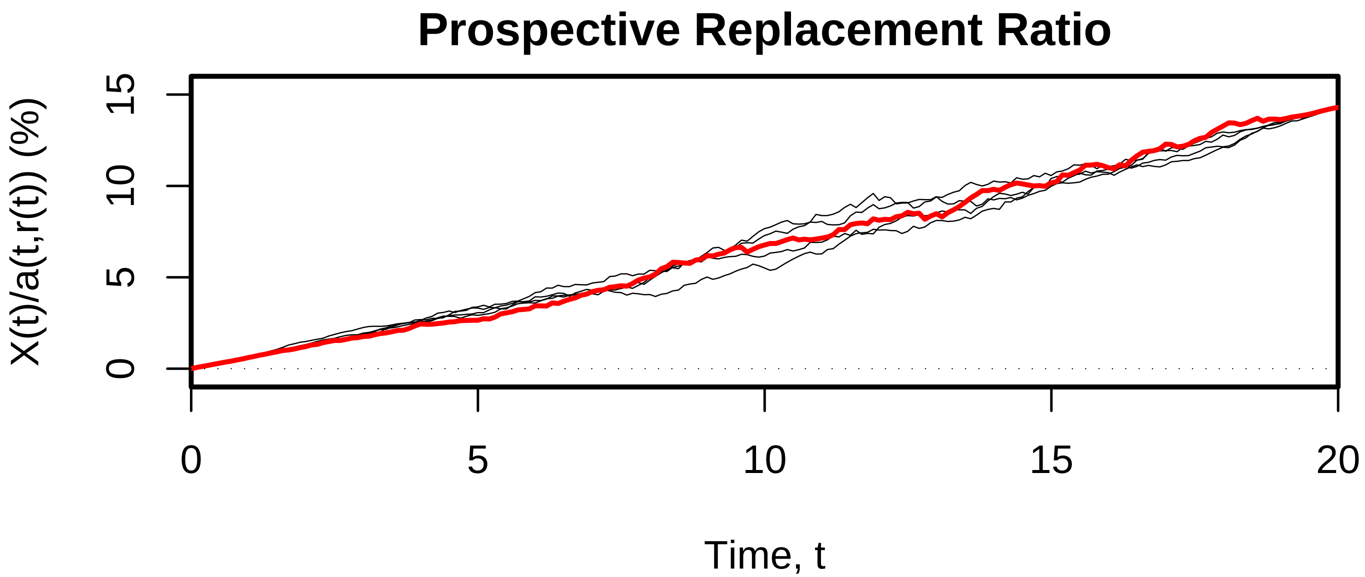


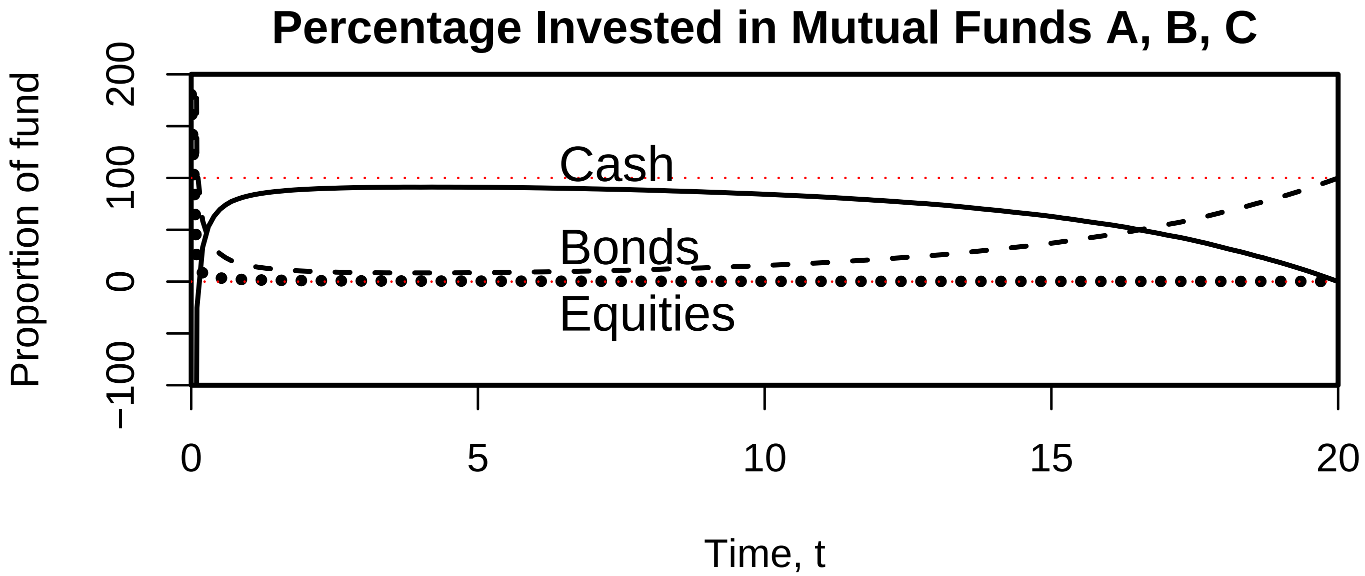



# Example 1: $RRA = 6, T = 20$



# Example 2: Very high $RRA$, $T = 20$



## Comparison with other strategies

Optimal strategy versus:

- Salary-hedged static strategy (S)
- Merton-static strategy (M)
- Deterministic lifestyle strategies:
  - initially 100% in equities
  - gradual switch over last 10 years into 100% bonds (B-10) or 100% cash (C-10)

Tables show:

- Cost:
  - Benchmark: 10% cont. rate with optimal strategy
  - Other strategies: % contribution rate to match optimal utility

    $\Rightarrow$ form of certainty equivalent

| (c) | $RRA = 6, \quad T = 20$ | | | | |
|---|---|---|---|---|---|
| Strategy: | Optimal stochastic | Static | | Deterministic lifestyle | |
| | | S | M | B-10 | C-10 |
| Cost | 10.00% | 10.61% | 11.55% | 10.71% | 11.39% |

- S: Salary-hedged static
- M: Merton static
- B-10: Deterministic lifestyle; switch to bonds over last 10 years
- C-10: Deterministic lifestyle; switch to cash over last 10 years

# The effect of policy term, $T$

| (c) | $RRA = 6, \quad T = 20$ | | | | |
|---|---|---|---|---|---|
| Strategy: | Optimal stochastic | Static | | Deterministic lifestyle | |
| | | S | M | B-10 | A-10 |
| Cost | 10.00% | 10.61% | 11.55% | 10.71% | 11.39% |

| (d) | $RRA = 6, \quad T = 40$ | | | | |
|---|---|---|---|---|---|
| Strategy: | Optimal stochastic | Static | | Deterministic lifestyle | |
| | | S | M | B-10 | A-10 |
| Cost | 10.00% | 11.52% | 12.58% | 12.86% | 13.67% |

| (b) | $RRA = 1, \quad T = 40$ | | | | |
|---|---|---|---|---|---|
| Strategy: | Optimal stochastic | Static | | Deterministic lifestyle | |
| | | S | M | B-10 | A-10 |
| Cost | 10.00% | 17.37% | 17.36% | 32.21% | 34.33% |

| (d) | $RRA = 6, \quad T = 40$ | | | | |
|---|---|---|---|---|---|
| Strategy: | Optimal stochastic | Static | | Deterministic lifestyle | |
| | | S | M | B-10 | A-10 |
| Cost | 10.00% | 11.52% | 12.58% | 12.86% | 13.67% |

| (f) | $RRA = 12, \quad T = 40$ | | | | |
|---|---|---|---|---|---|
| Strategy: | Optimal stochastic | Static | | Deterministic lifestyle | |
| | | S | M | B-10 | A-10 |
| Cost | 10.00% | 12.38% | 13.17% | 16.57% | 17.82% |

## Fixed Retirement: Conclusions

- Commercial strategies can be costly
- Optimal strategy has some drawbacks:
  - regular rebalancing $\Rightarrow$ difficult to implement??
  - short selling

$\Rightarrow$ we need to find a compromise

$\Rightarrow$ future work to find a robust dynamic strategy that takes account of plan member's risk aversion

# Fixed Retirement: Conclusions

- Even under optimal stochastic strategies

  pension ratio at 65 is very uncertain

  $\Rightarrow$ Increasing use of flexible retirement ages

Next step: go to the other extreme:

Retire when Pension Ratio $= 2/3$ of current salary

# Basic model

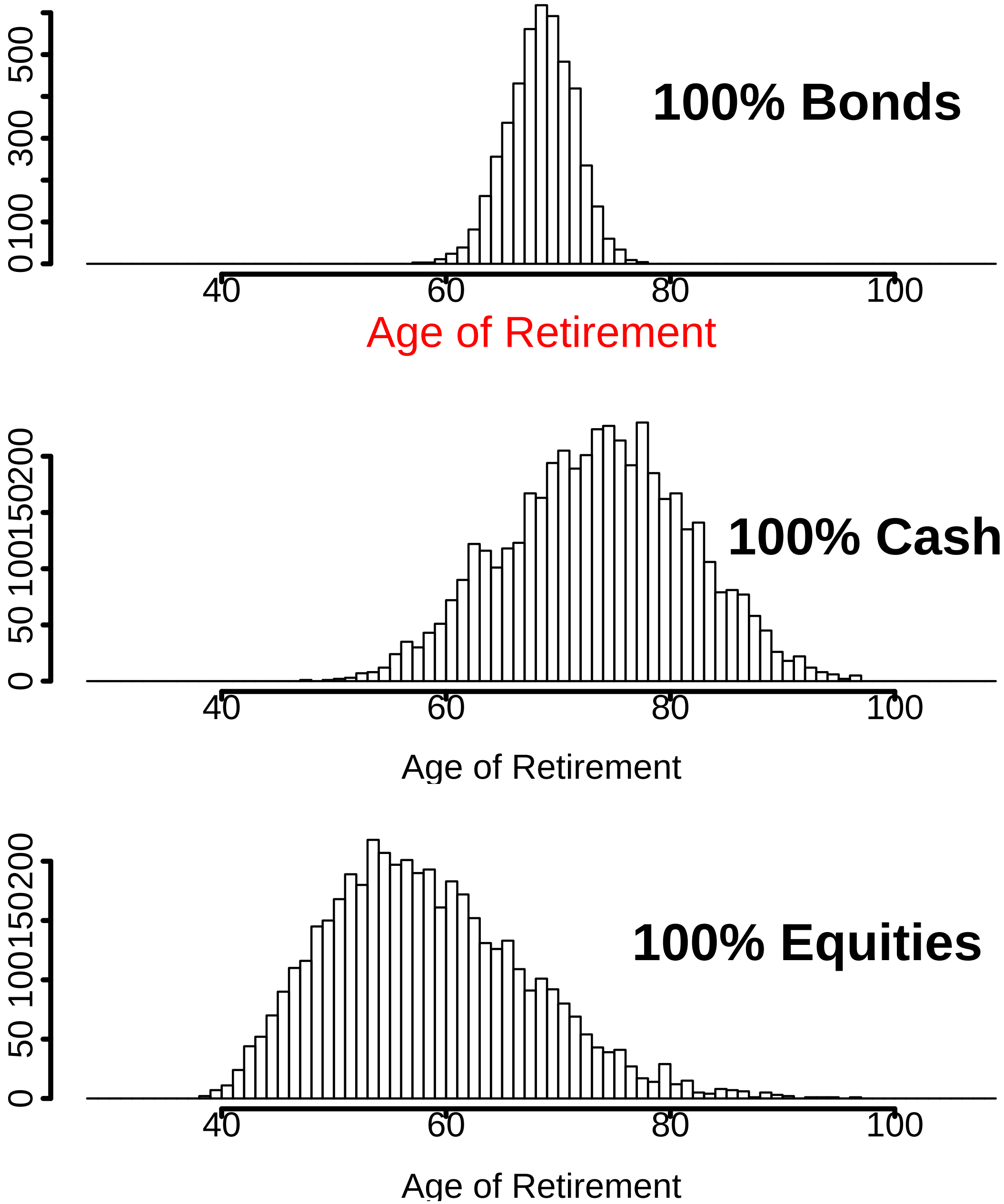
- Interest rates: Vasicek, risk-free rate $r(t)$
- Assets:
  - Cash account
  - Long-dated bond
  - Equities
- Fixed salary growth rate

## Replacement ratio

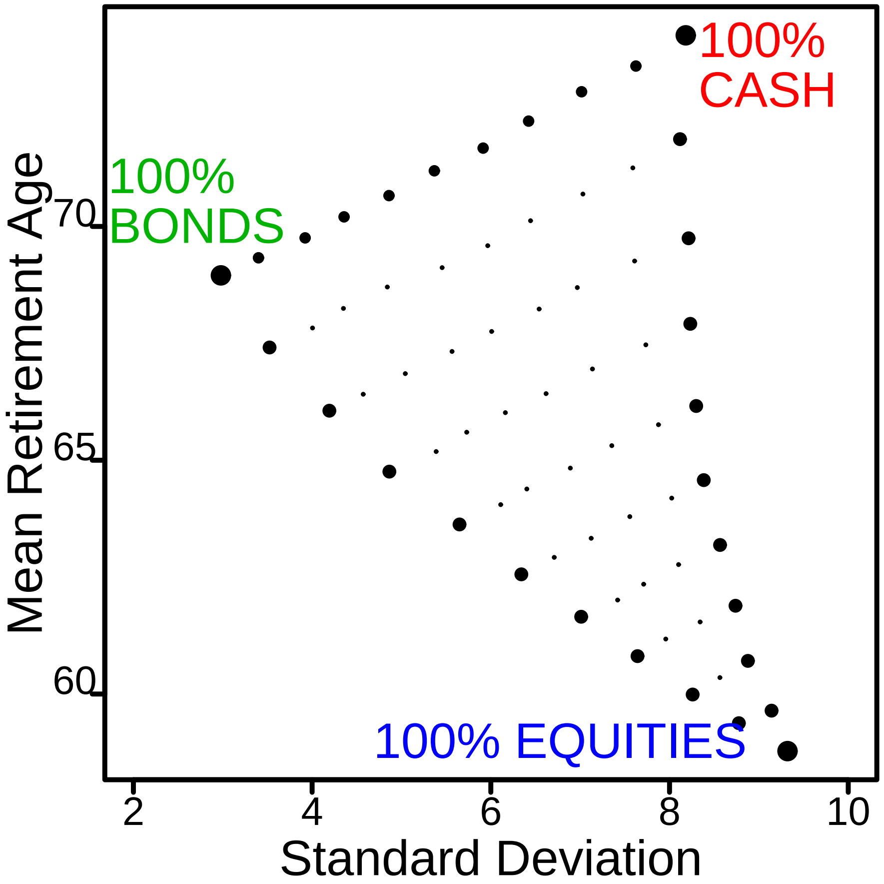
$$RR(t) = \frac{\text{Wealth}(t)/\ddot{a}(x+t, r(t))}{\text{Salary}(t)}$$

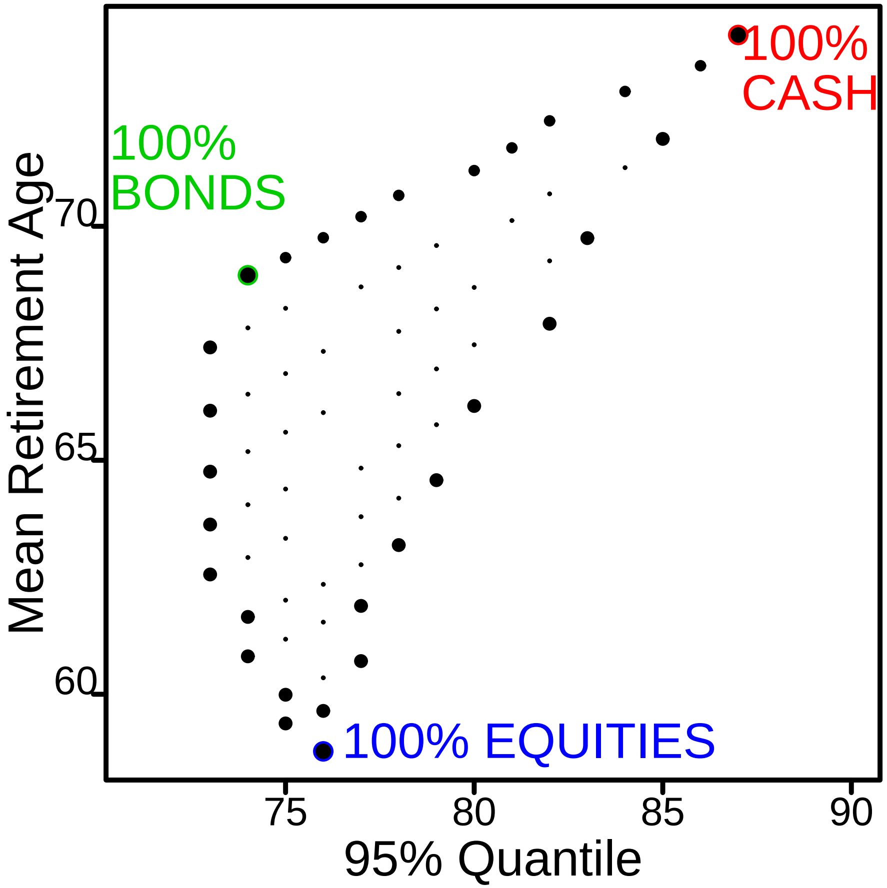
Retire when $RR(t) \geq 2/3$

- What is the distribution of the age of retirement?
- How does it depend on the investment mix?
- What is the impact on the size of the working population?


0100 300 500
40 60 80 100
Age of Retirement
100% Bonds
0 50 100150200
40 60 80 100
Age of Retirement
100% Cash
0 50 100150200
40 60 80 100
Age of Retirement
100% Equities

# Risk-Return opportunity sets




Percentages in (Cash, Bonds, Equities)

# Impact on population dynamics

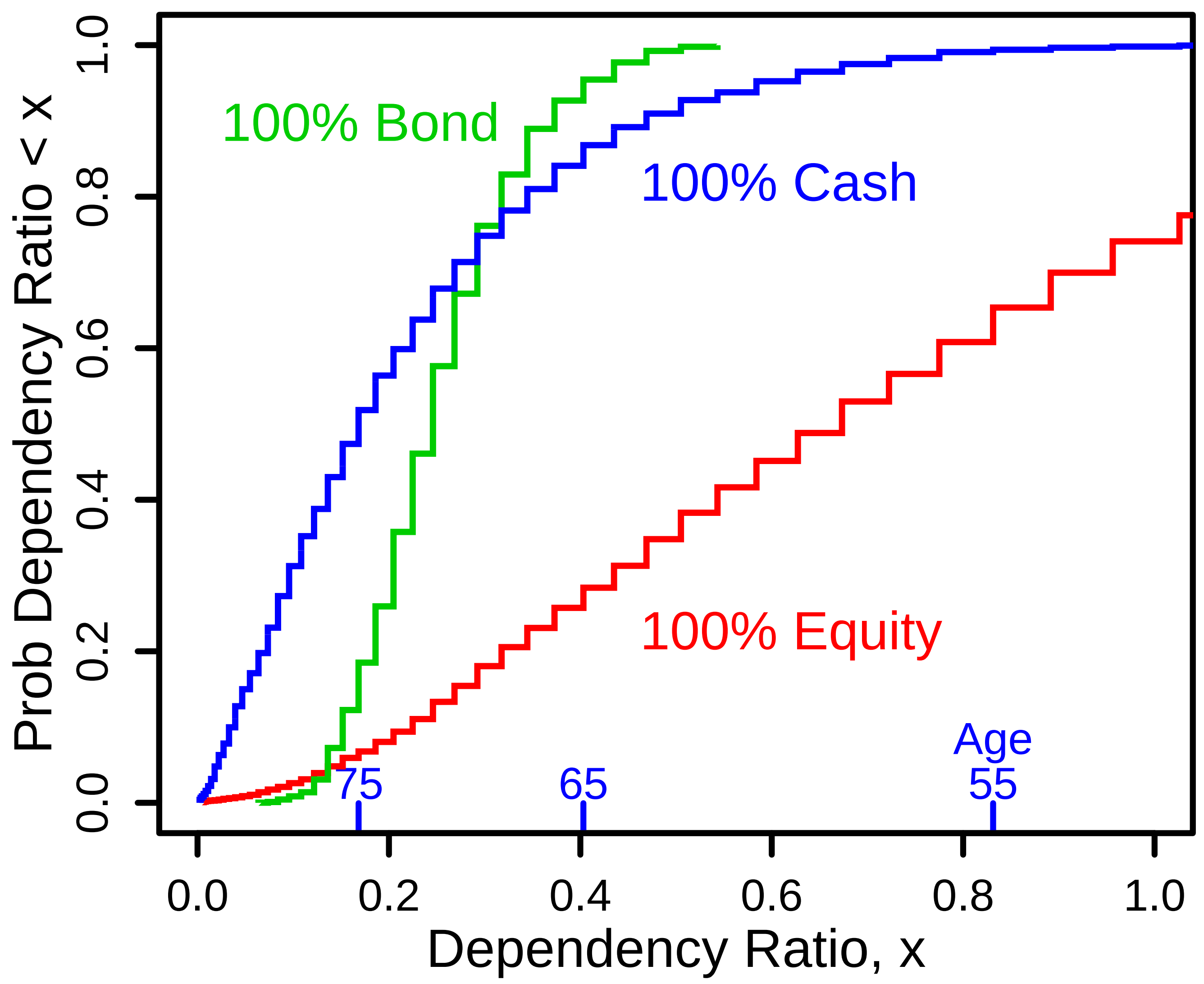
- Assume:
  - stable population
  - stable mortality rates
  - all individuals enter working population at 25
  - retirement according to 2/3 rule
  - all individuals follow the same investment strategy

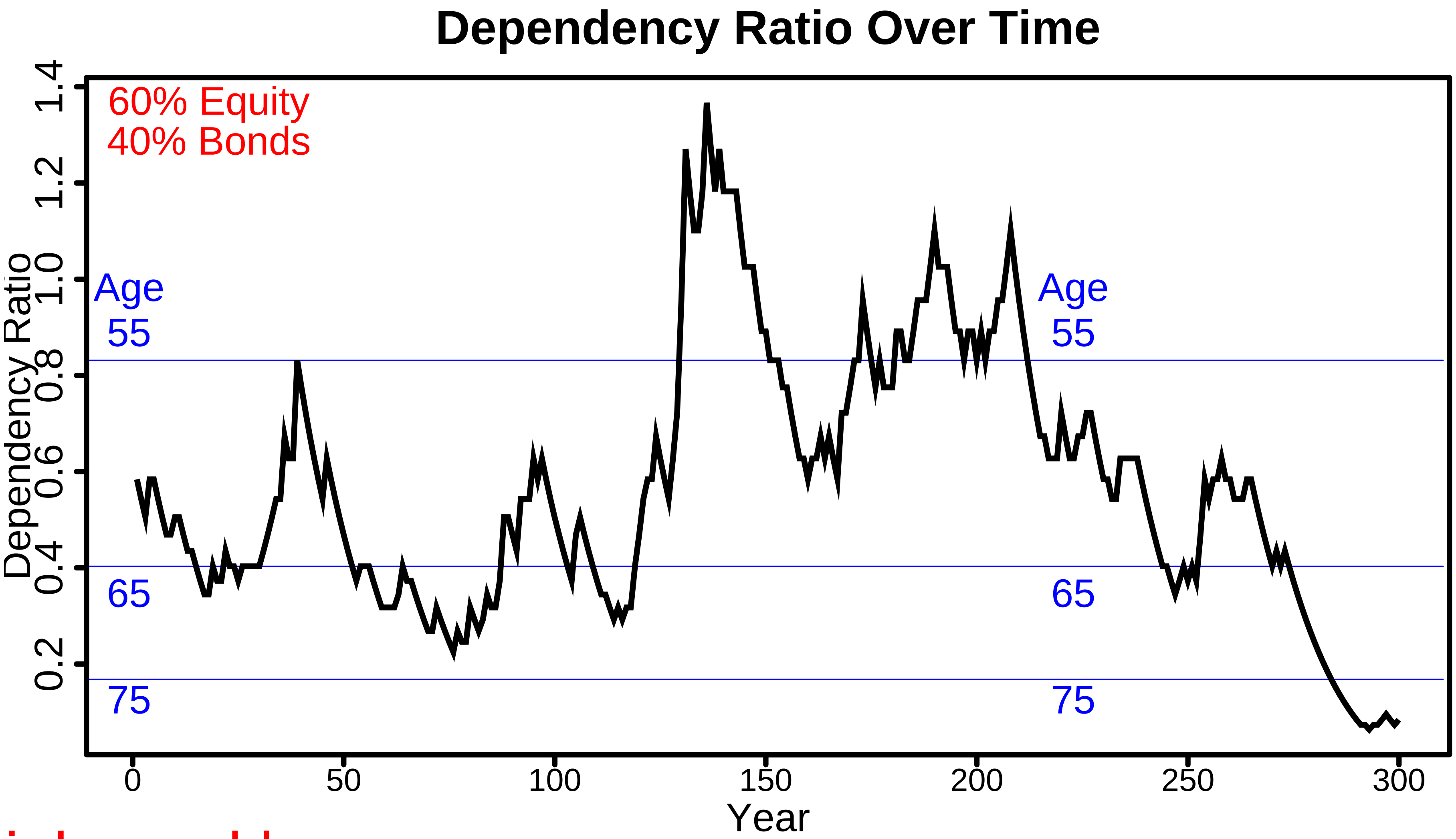
# Impact on population dynamics

$$\text{Dependency Ratio} = \frac{\#\ \text{retired population}}{\#\ \text{working population}}$$

| Age of youngest retiree | 55 | 65 | 75 |
|---|---|---|---|
| Dependency ratio | 0.83 | 0.40 | 0.17 |

Low dependency ratio $\Rightarrow +$ and $-$


100% Bond
100% Cash
100% Equity
Age
75
65
55
Prob Dependency Ratio < x
0.0
0.2
0.4
0.6
0.8
1.0
Dependency Ratio, x
0.0
0.2
0.4
0.6
0.8
1.0




Highs and lows:

strongly correlated with exp.-weighted investment returns

## Observations

- “Extreme” criterion applied $\Rightarrow$

  substantial swings in working population

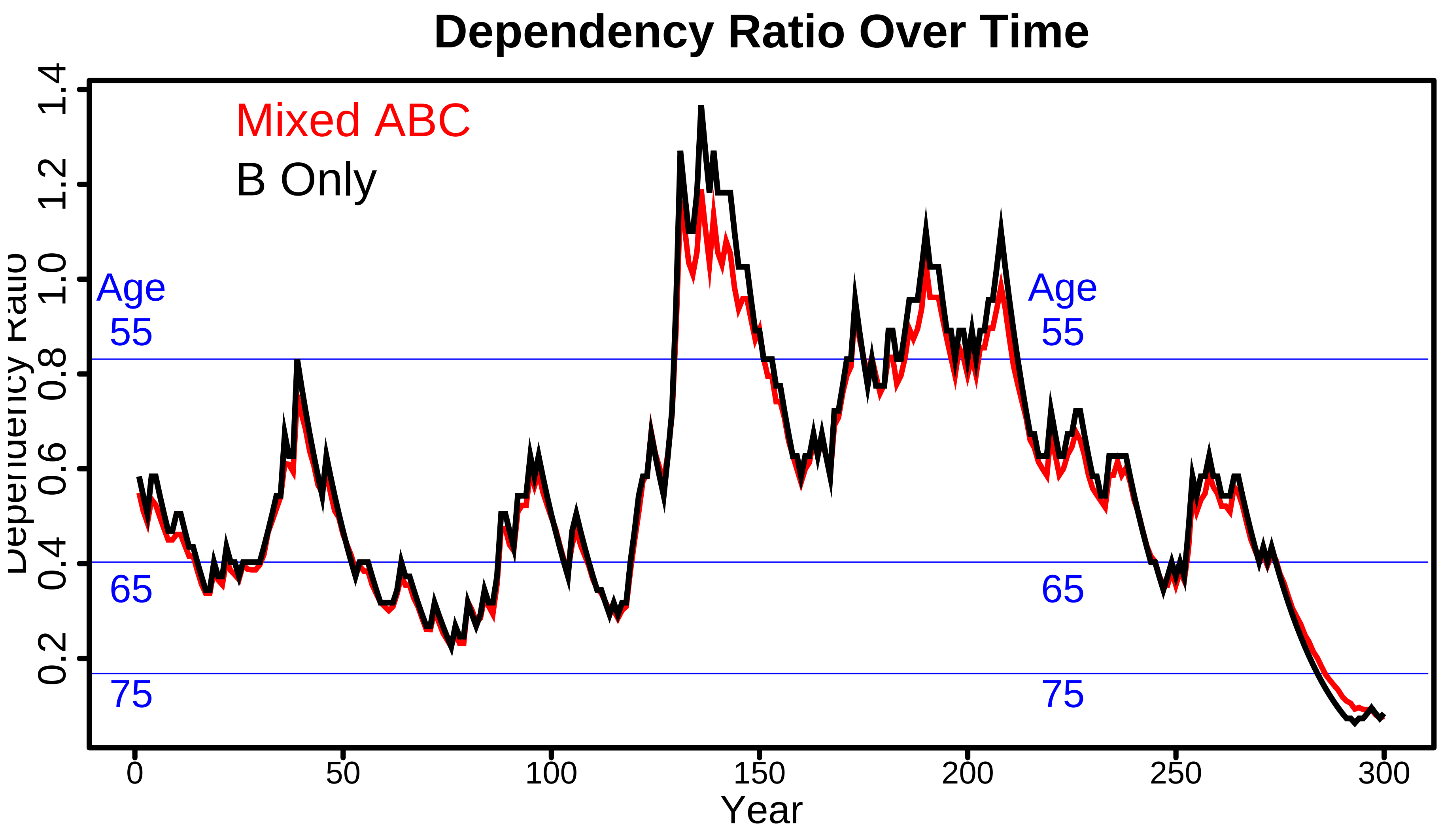
- Introducing heterogeneity:
  - mixed investment strategies
  - mixed retirement strategies
  - stochastic salaries

# Heterogeneity in investment strategies

Each plan member follows one of three investment strategies

| | Strategy | % Bonds | % Equities |
|---|---|---|---|
| A | Low risk | 80 | 20 |
| B | Medium risk | 40 | 60 |
| C | High risk | 0 | 100 |

1/3 of members for each strategy




Investment heterogeneity has little effect

## Reason

- Long-term investments in A, B and C are highly correlated
- Annuity purchase at the same rates for A, B, C
  - driver is short-term interest rate $r(t)$
  - different mean returns
  - but periods of high growth for A, B, C coincide

## Why are these fluctuations undesirable?

- Substantial late-retirement risk for plan members
- “Dependency ratio” relevant to
  - how to pay for pre-working population
  - how to pay for pensioners with state pension only
- fluctuations in working population $\Rightarrow$
  - impact on economy
  - impact on tax take

## Is it possible to smooth out the fluctuations?

Work in progress:

- stochastic price inflation and salaries
- heterogeneity in:
  - retirement decisions
  - contribution rate
  - entry age to plan
  - career flight path
  - annuity type

Which of these are important for smoothing?

## Conclusions

- DC pensions load risk onto plan members
- Need to develop better dynamic investment strategies
- Potential demographic timebomb
  - flexible retirement ages are inevitable
  - pension system needs to be designed to avoid big fluctuations in working population

- Blake, D., Cairns, A.J.G., and Dowd, K., (2001)

  Pensionmetrics: Stochastic pension plan design and value-at-risk during the accumulation phase

  *Insurance: Mathematics and Economics*

- Cairns, A.J.G., Blake, D., and Dowd, K., (2004)

  Stochastic Lifestyling: Optimal Dynamic Asset Allocation for Defined Contribution Pension Plans

  To appear in the *Journal of Economic Dynamics and Control*

- MacDonald, B.-J. and Cairns, A.J.G., (2005)

  DC Pension Plans For All: What If?

  *AFIR 2005, Zurich*


http://www.ma.hw.ac.uk/∼andrewc/papers