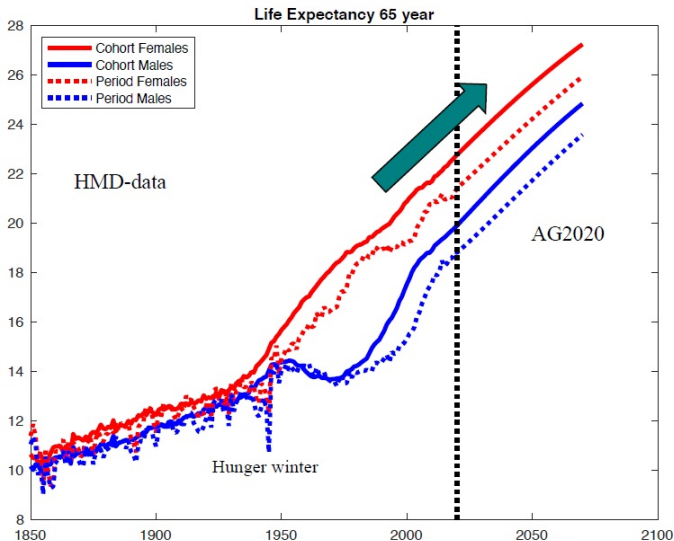


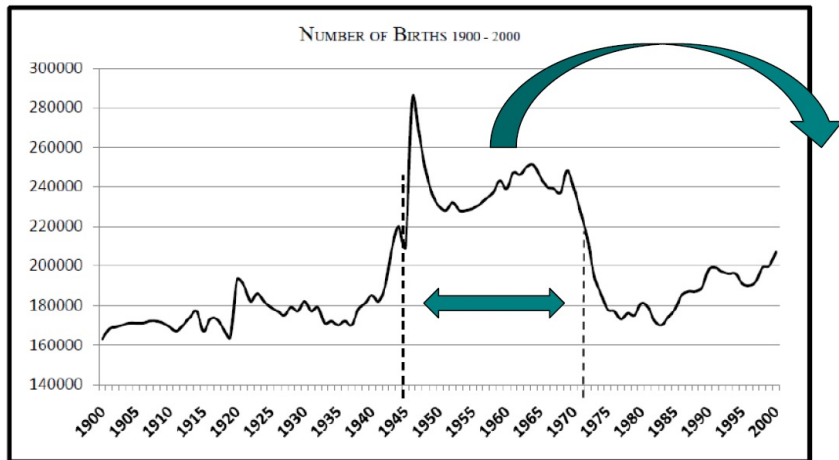
- 1 Introduction
- 2 Relevance of Macro Longevity Risk
  - First Pillar: AOW
  - Second Pillar: Pension Funds
- 3 Modeling Mortality
- 4 Benchmark Model
  - The Lee-Carter Model
  - Alternative Estimation
  - Some Applications and Extensions
- 5 The AG2022 Model and COVID-19
  - Model and Projections
  - Closure of the Life Table
- 6 Model Risk: A Very Brief Introduction

- AOW is the basic pension in the Netherlands that everyone gets, who lived in the Netherlands.
- This pillar is not related to how much the retiree worked.
- The pension depends on how many years the retiree lived in the Netherlands before retirement.
- If the retiree lived the fifty years before retirement in the Netherlands, he/she gets the full amount. If someone lived a shorter period of time in the Netherlands, this amount will be scaled down proportionally.
- Changes in life expectancy can affect whether the government can afford AOW.
  - Life expectancy has increased dramatically during the last decades.
  - It is unclear whether and how it will continue to increase (macro longevity risk).
- Other factors such as the number of newborns influence the stability and sustainability of the pension system.

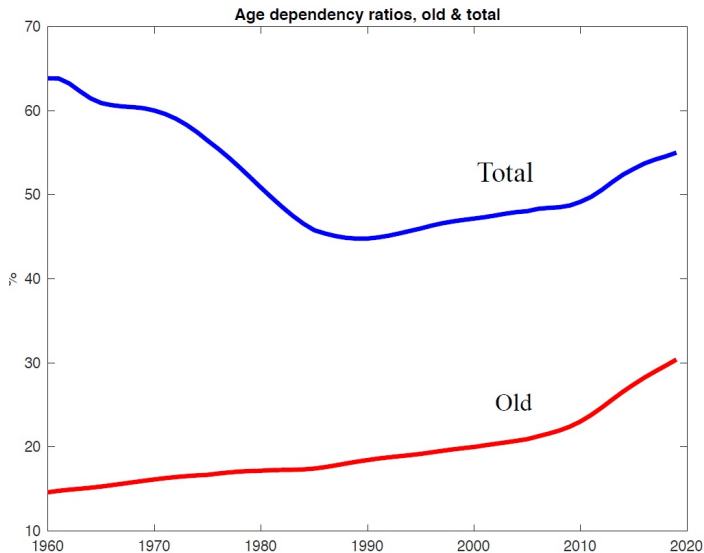
# Increase in Life Expectancy



# Number of Newborns (Source: CBS)



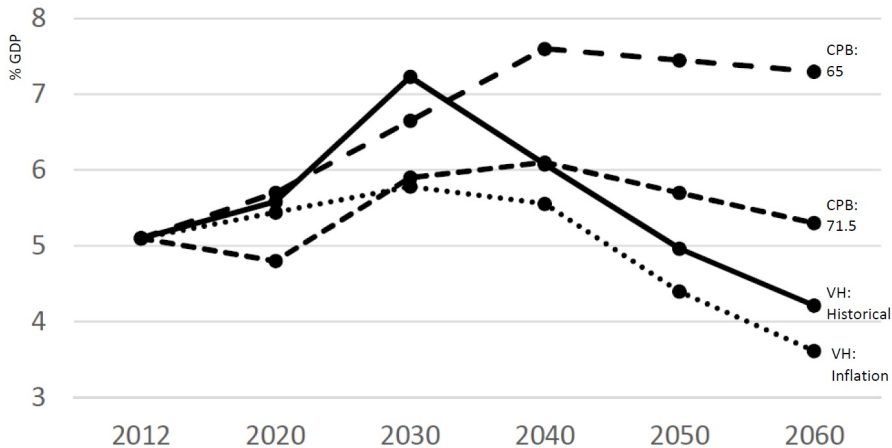
# Dependency Ratio (Source: World Bank)



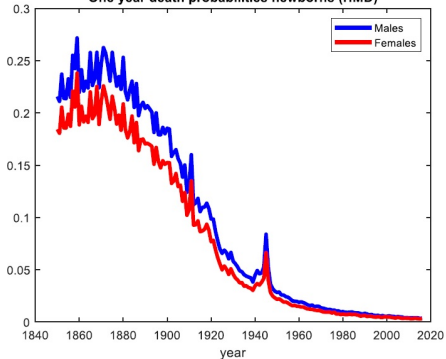
$$\frac{\text{Young \& Old}}{\text{Working}}$$

$$\frac{\text{Old}}{\text{Working}}$$

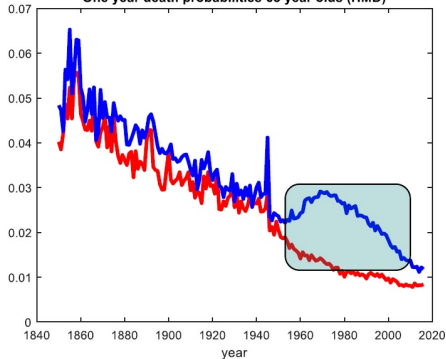
# Possible Future Scenarios (Source: CBS)

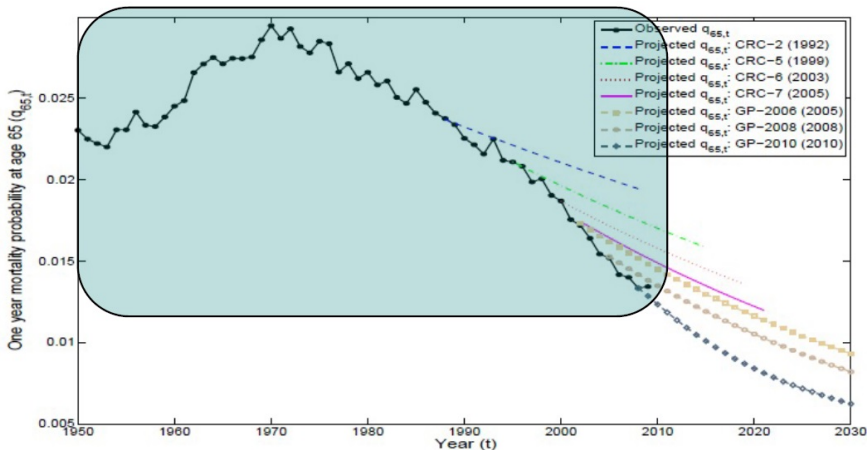


One year death probabilities newborns (HMD)



One year death probabilities 65 year olds (HMD)



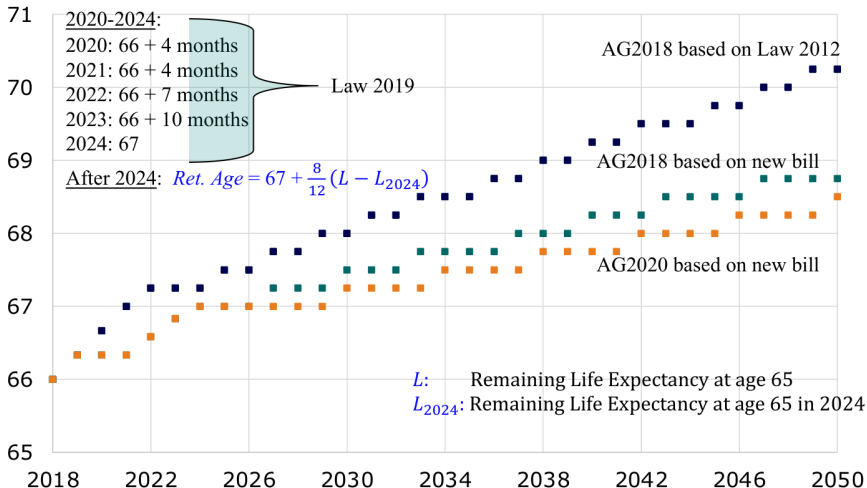


- Best estimate projections were wrong in the past!
- Macro Longevity Risk: Need to quantify the uncertainty around the projections as well.

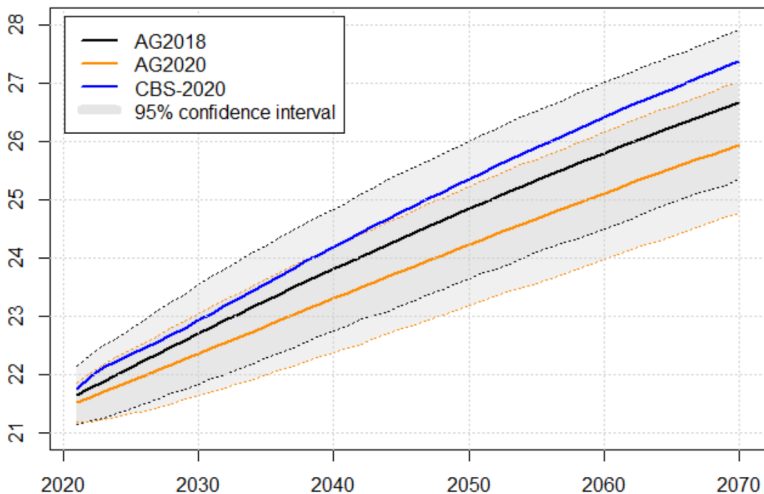


- Statistics Netherlands (CBS) and the Royal Dutch Actuarial Association produce point forecasts for future one-year death probabilities by age and gender.  
→ Are available on the website of the AG.
- These point forecasts (“best-estimate” death probabilities) are nowadays based on underlying models. These models can also be used to quantify macro longevity risk, for example, in terms of confidence intervals around the point forecasts.
- Part III of the course is going to illustrate this.
  - The models are not only used to derive the best estimates.
  - They can also be used to estimate confidence intervals describing the uncertainty around the point estimates.

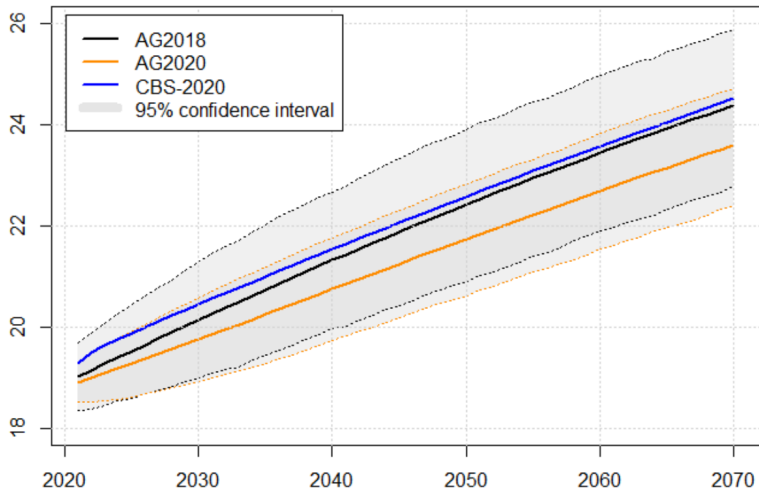
# Illustrating Macro Longevity Risk



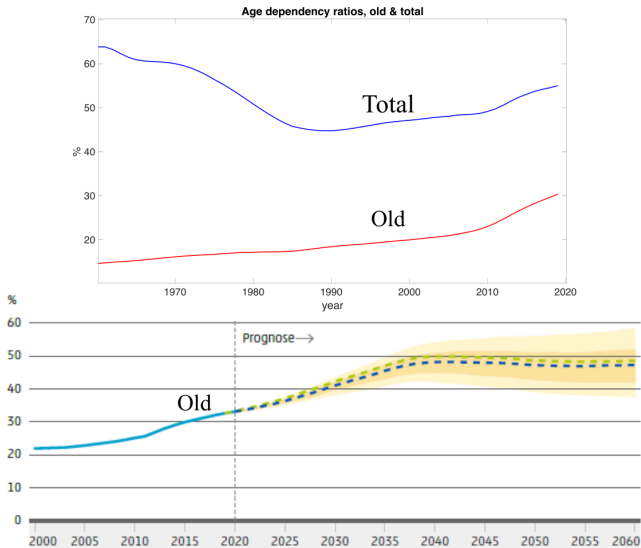
## Period life expectancy for females at age 65



## Period life expectancy for males at age 65



# Illustrating Macro Longevity Risk



- Describes the build-up of pension entitlements.
  - Many different contracts.
  - Alternative build-up percentages (around 2%).
  - Alternative ambitions (nominal, real).
  - Alternative indexation rules (price inflation, wage inflation).
- Changes all the time...
- New pension contract under construction...

- Building up entitlements (for some given year  $t$ ):

$$\pi_x = \sum_{\tau=T_{Ret,x}}^{\infty} \tau-x p_x \frac{f_x}{(1 + R(\tau - x))^{\tau-x}}$$

- Notation:

$x$  : age

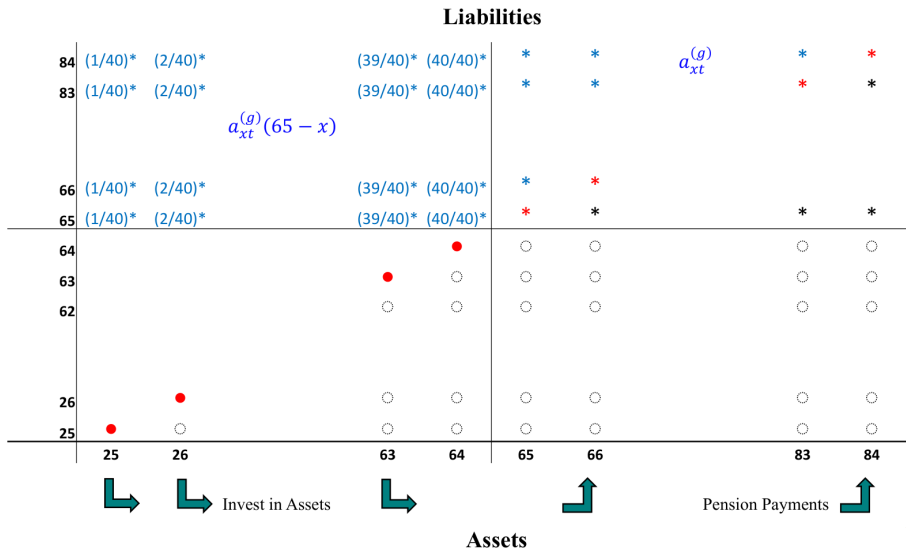
$\pi_x$  : pension contribution

$f_x$  : pension entitlement per year

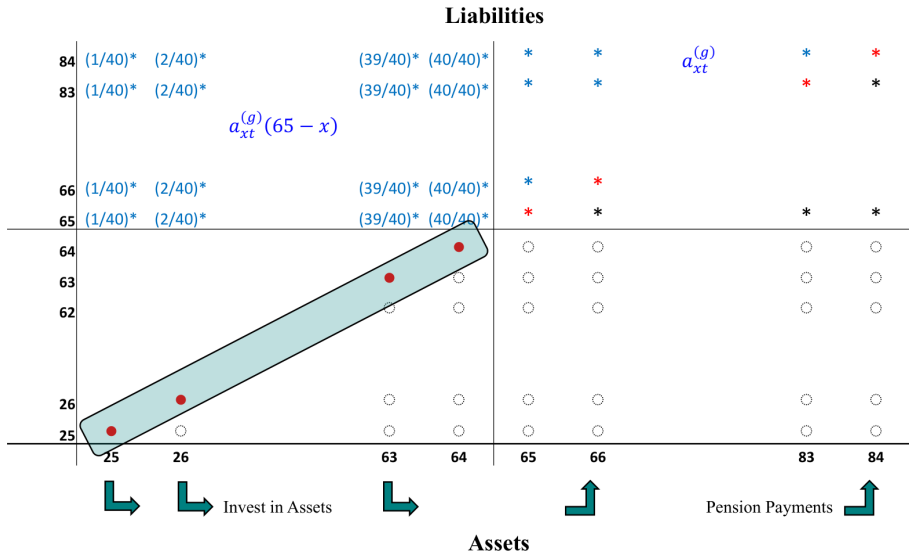
${}_{\tau-x}p_x$  :  $(\tau - x)$ -years survival probability of an individual of age  $x$

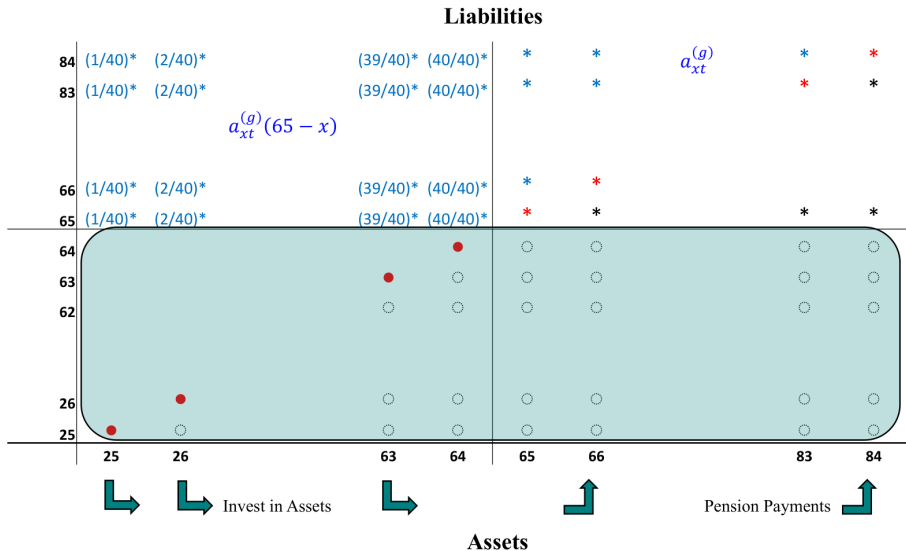
$R(\tau - x)$  : discount rate with maturity  $(\tau - x)$  years

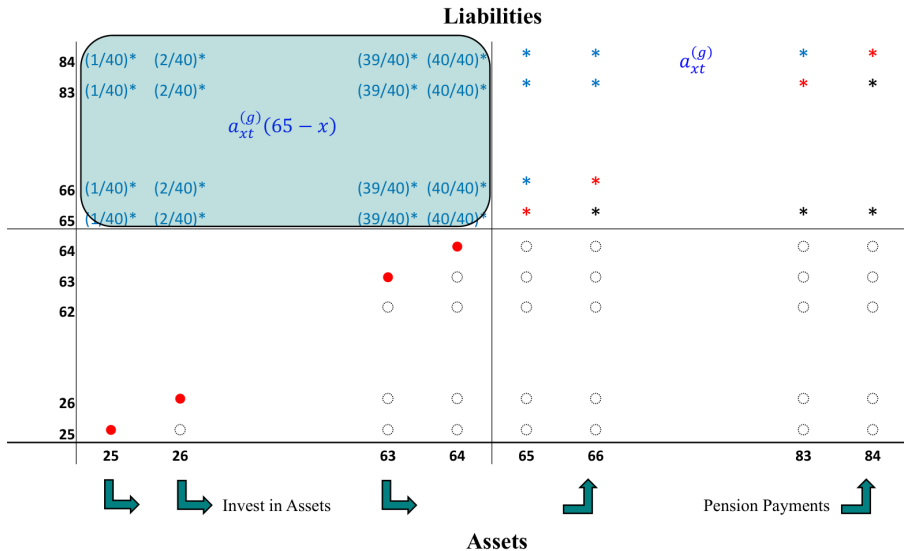
$T_{Ret,x}$  : retirement age for the generation of age  $x$



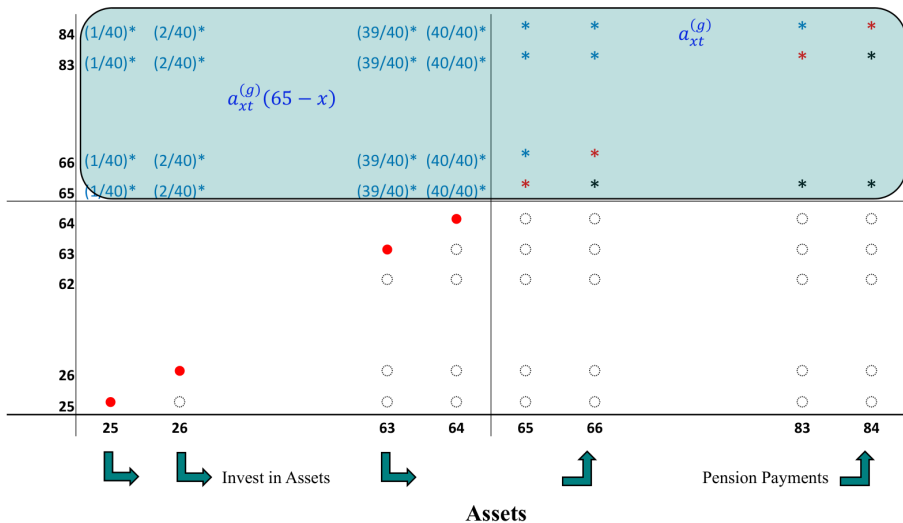




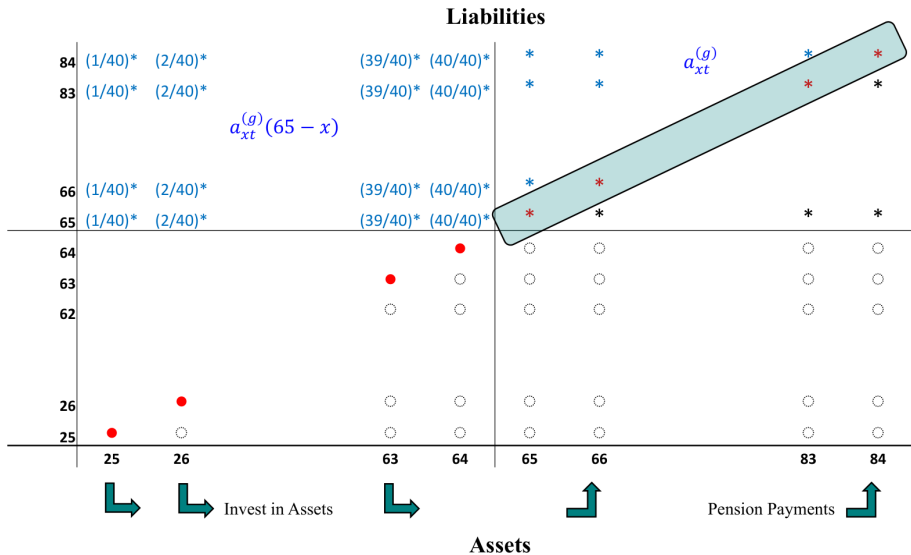




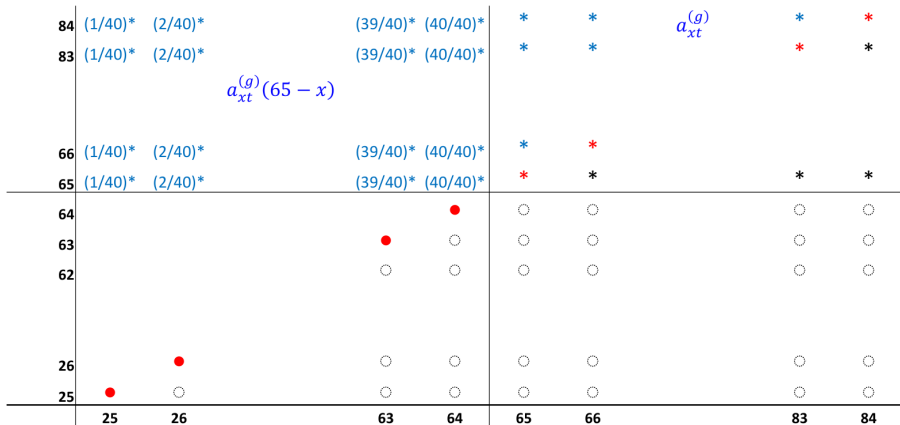
## Liabilities



## Assets

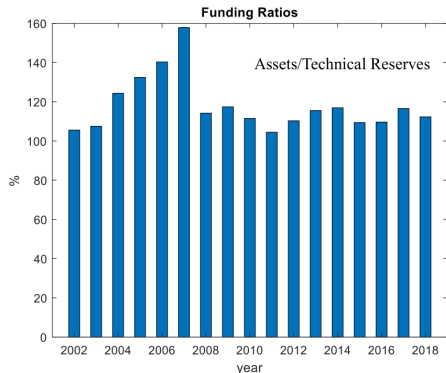
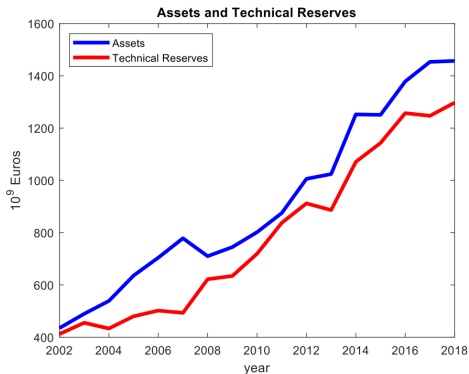


## Liabilities



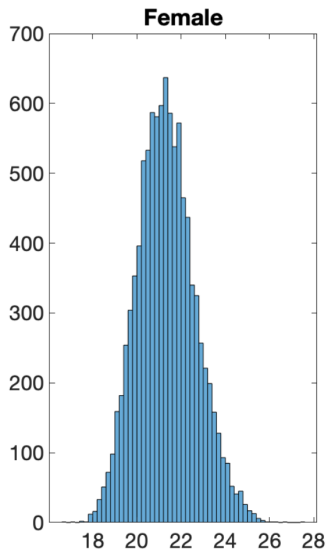
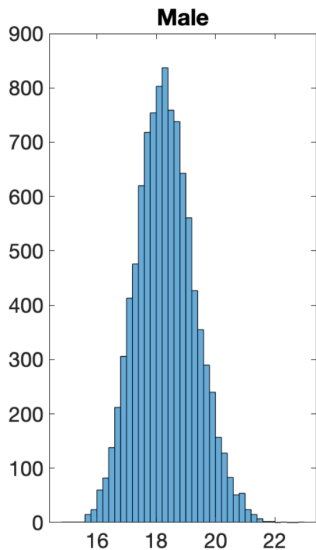
- Balance sheet of a pension fund:

- Funding Ratio (FR) = Assets/Liabilities.





# Simulation: Annuity Factor (see Part IV)



# Simulation: Funding Ratios (see Part IV)

