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Cash Balance Plans:
Valuation and Risk Management

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Outline

1. Background
2. Framework, assumptions, notation
3. The valuation formulas
4. Some results
5. Funding and Valuation
6. Final thoughts

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Cash Balance Pensions

- Look like DC
  - contribution (% of salary) paid into participant’s account
  - account accumulates to retirement
  - lump sum retirement benefit
  - withdrawal benefit =account value (after vesting)
- Regulated like DB
- Participant accounts are nominal

Crediting rates

- Participant's account accumulates at specified *crediting rate*.
- For example
  - Yield on 30-year government bonds
  - Yield on 10-year government bonds
  - Yield on 5-year government bonds + 25bp
  - Yield on 1-year government bonds + 100bp
  - Fixed rate, eg 5% p.y.
  - CPI rate

Some statistics...

- In 2010, 12 million CB participants in US
- Early popularity with sponsors, late 1990s
  - Simple transition from traditional DB to CB
    - Compared with DB to DC transition
  - Tax benefits
  - More transparent (apparently)
  - Less contribution volatility (apparently)
- With participants..
  - More portable, more transparent
  - But transition problems for older members

Framework, assumptions, notation

- Participant with *n* years service at valuation date.
- At valuation $t=0$.
- Retires at *T* with $n+T$ years
- Ignore exits, annuitization.
- Value future benefit arising from past contributions
- Use market valuation methods
  - Generates the cost of transferring the pension liability to capital markets

Framework, assumptions, notation

- F_t denotes the participant's fund at t
- $i^c(t)$, $r^{\,c}(t)$ denote the crediting rates at t
- $r_k(t)$ denotes the k-year spot rate at t
- $r(t)$ denotes the short rate at t
- $p(t, t+k)$ denotes the price at t of a \$1, k-year zero coupon bond.

Framework, assumptions, notation

- Recall that

$$p(t,t+k) = e^{-k\,r_k(t)}$$

- Using financial valuation principles, we also have

$$p(t,t+k) = \mathrm{E}_t^Q\left[\exp\left\{-\int_t^{t+k} r(s)ds\right\}\right]$$

Framework, assumptions, notation

- Assume continuous crediting, given F_t

$$F_T = F_t \exp\left\{ \int_t^T r^c(s)\, ds \right\}$$

- This is a random variable unless the crediting rate is constant.

The Valuation Formula

- The market value at t=0 of the benefit F_T is

$$ {}_0V = E_0^Q\left[F_T \, e^{-\int_0^T r(s)ds} \right] = F_0 \, E_0^Q\left[\left(e^{\int_0^T r^c(s)ds} \right)\left(e^{-\int_0^T r(s)ds} \right) \right] $$

$$ = F_0 \, E_0^Q\left[e^{\int_0^T \left(r^c(s) - r(s) \right) ds} \right] $$

The Valuation Formula

- We let

$$V(t,T) = E_t^Q\left[\exp\left\{\int_t^T r^c(s) - r(s)\,ds\right\}\right]$$

That is

- *V(t,T)* = market value at t of CB benefit at T
  - per $1 of nominal fund at *t*
  - No exits
  - No future contributions
  - With continuous compounding

Fixed crediting rate

- Suppose $r^c(t)$ is constant, $=r^c$, say
- Then

$$V(0,T) = E_0^Q\left[\exp\left\{\int_0^T r^c(s) - r(s)\,ds\right\}\right]$$

$$= \exp(Tr^c)\,E_0^Q\left[\exp\left\{-\int_0^T r(s)\,ds\right\}\right]$$

$$= \exp(Tr^c)\,p(0,T)$$

- The T-year zcb price *p(0,T)*, is known at $t=0$

Fixed crediting rate

- For example, $r^c = \log(1.05)$
- Using US yield curve at 1/April/2013

  V(0,5) = $(1.05)^5$ (0.96256) = 1.2285

  V(0,10) = $(1.05)^{10}$ (0.82250) = 1.3398

  V(0,20) = $(1.05)^{20}$ (0.58889) = 1.5626

- That is, with a 10-year horizon to retirement, every $1 of fund or contribution costs $1.4375
- Model-free valuation result.

Crediting with the short rate

- Suppose the crediting rate is the short rate plus a fixed margin m
  - That is $r^c(t) = r(t) + m$, then

$$V(0,T) = E_0^Q\left[\exp\left\{\int_0^T r^c(s) - r(s)\,ds\right\}\right]$$

$$= E_0^Q\left[\exp\left\{\int_0^T r(s) + m - r(s)\,ds\right\}\right]$$

$$= e^{mT}$$

Crediting with the short rate

- For example, $r^c(t) = r(t) + m$, with $m = 0.0175$
  - Then

    V(0,5) = e^{5m} = 1.09144

    V(0,10) = e^{10m} = 1.19125

    V(0,20) = e^{20m} = 1.41908

- This will be $\approx$ to the valuation for 3-month T-bill +175bp crediting rates.
- Model-free

Crediting with *k*-year spot rates

- Crediting with $r^c(t) = r_k(t) + m$
- We need a market model for $r_k(t)$
- We use one-factor Hull-White / ext Vasicek model

$$dr(t) = a\left(\theta(t) - r(t)\right)dt + \sigma dW_t$$

$$p(t,t+k) = \exp\left\{A(t,t+k) - B(t,t+k)r(t)\right\}$$

  - Where *B(t,t+k)* is a function of *a, k*
  - *A(t,t+k)* is a function of yield curve at *t* and H-W parameters

Crediting with *k*-year spot rates

- After some manipulation….

$$V(0,T) = e^{mT} \exp\left(-\int_0^T \frac{A(t,t+k)}{k} dt \right) \mathrm{E}_0^Q \left[\exp\left(-\int_0^T \gamma r(t) dt \right) \right]$$

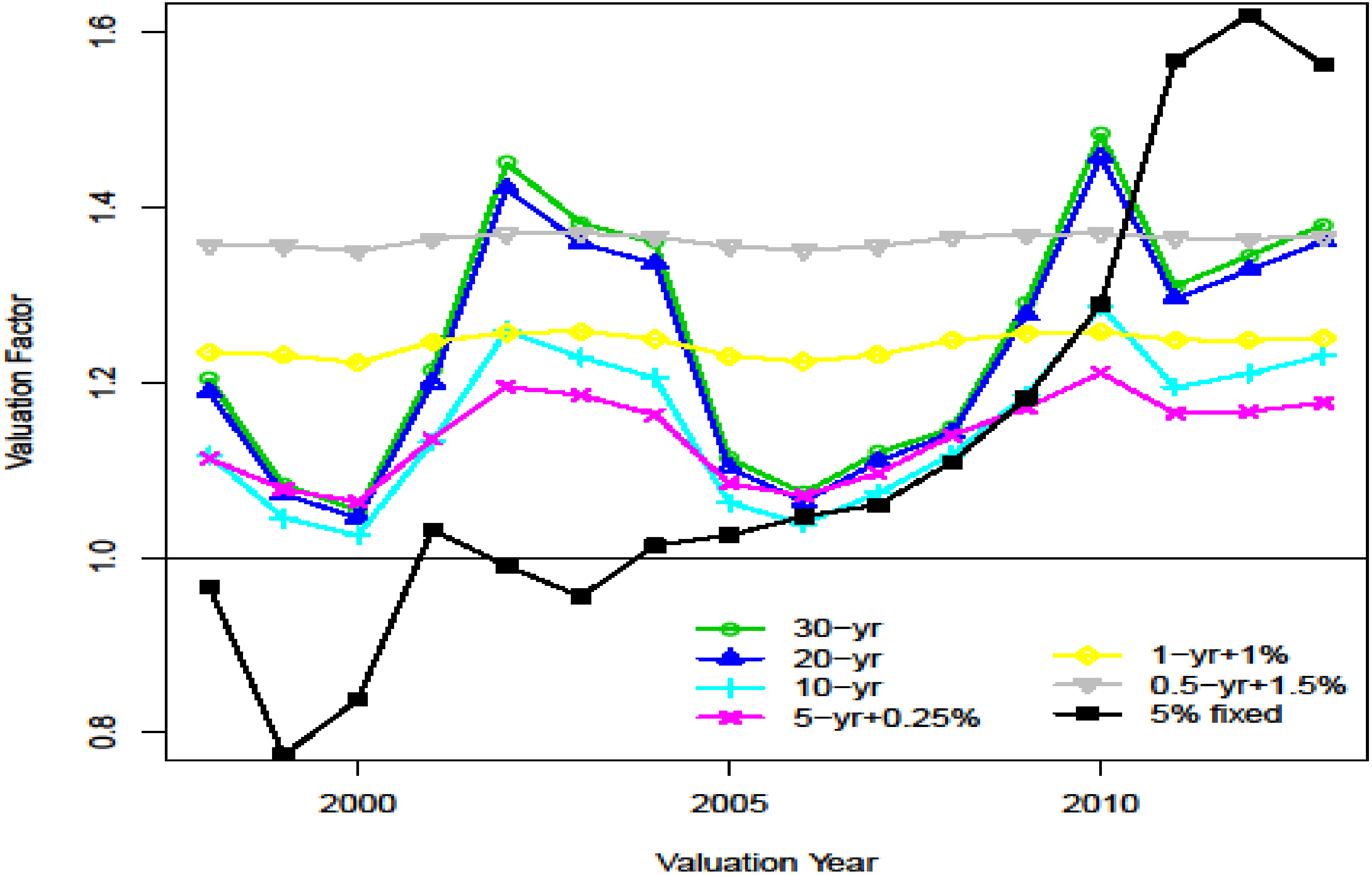
where $$\gamma = 1 - \left(\frac{1-e^{-ak}}{ak} \right)$$

- The second term is evaluated using numerical integration (partly).
- The third term can be solved analytically – similar to the case γ=1

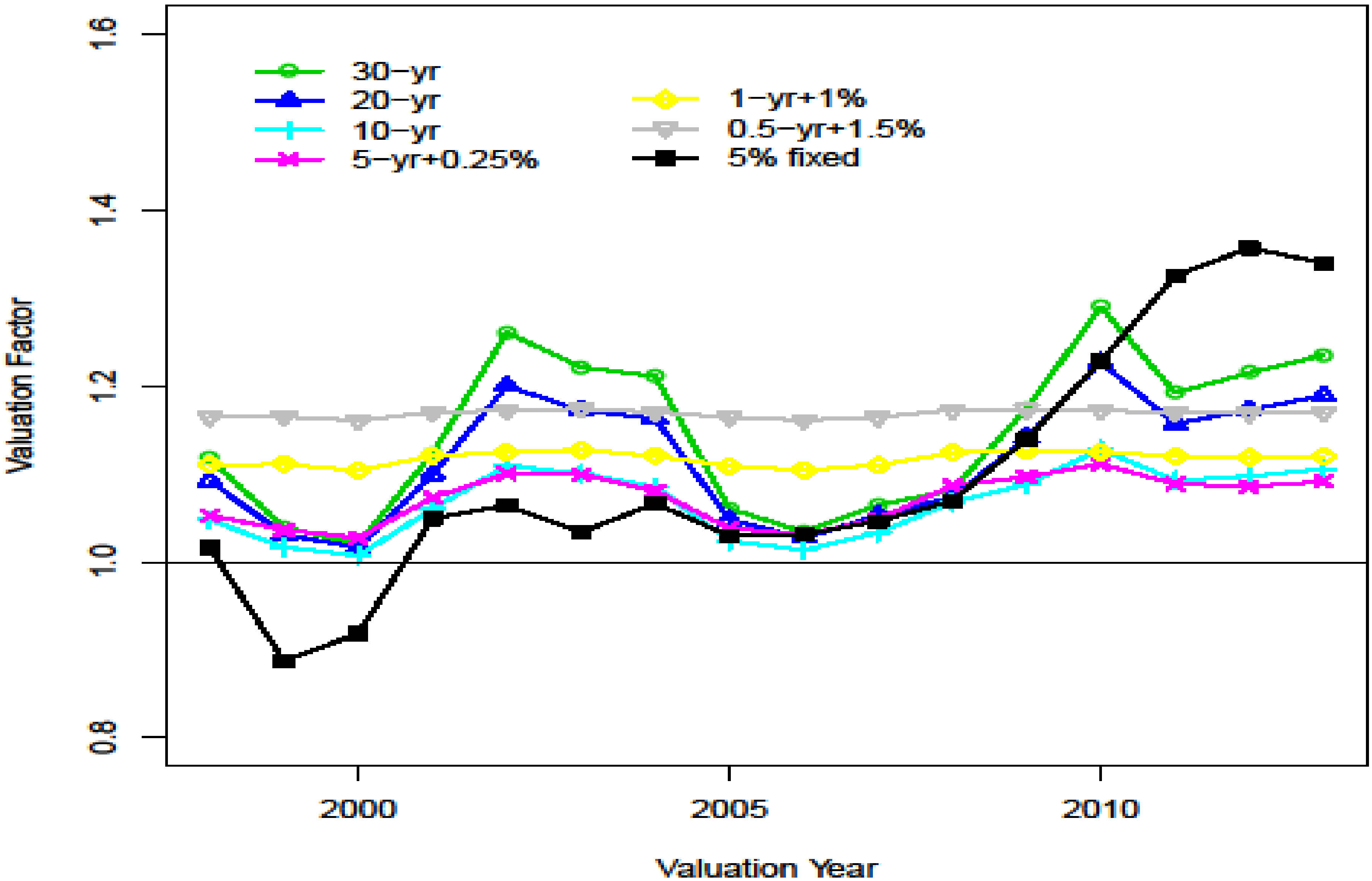
Crediting with k-year spot rates

- For illustration we use
  - $a = 0.02$, $\sigma = 0.006$
  - T=5, 10, 20 years
    - $r^c(t)$= 30-yr spot rate | 20-yr spot rate | 10-yr spot rate | 5-yr + 25bp | 1-yr + 100bp | 0.5-yr+150bp
  - Yield curve from US treasuries 1998, …, 2013

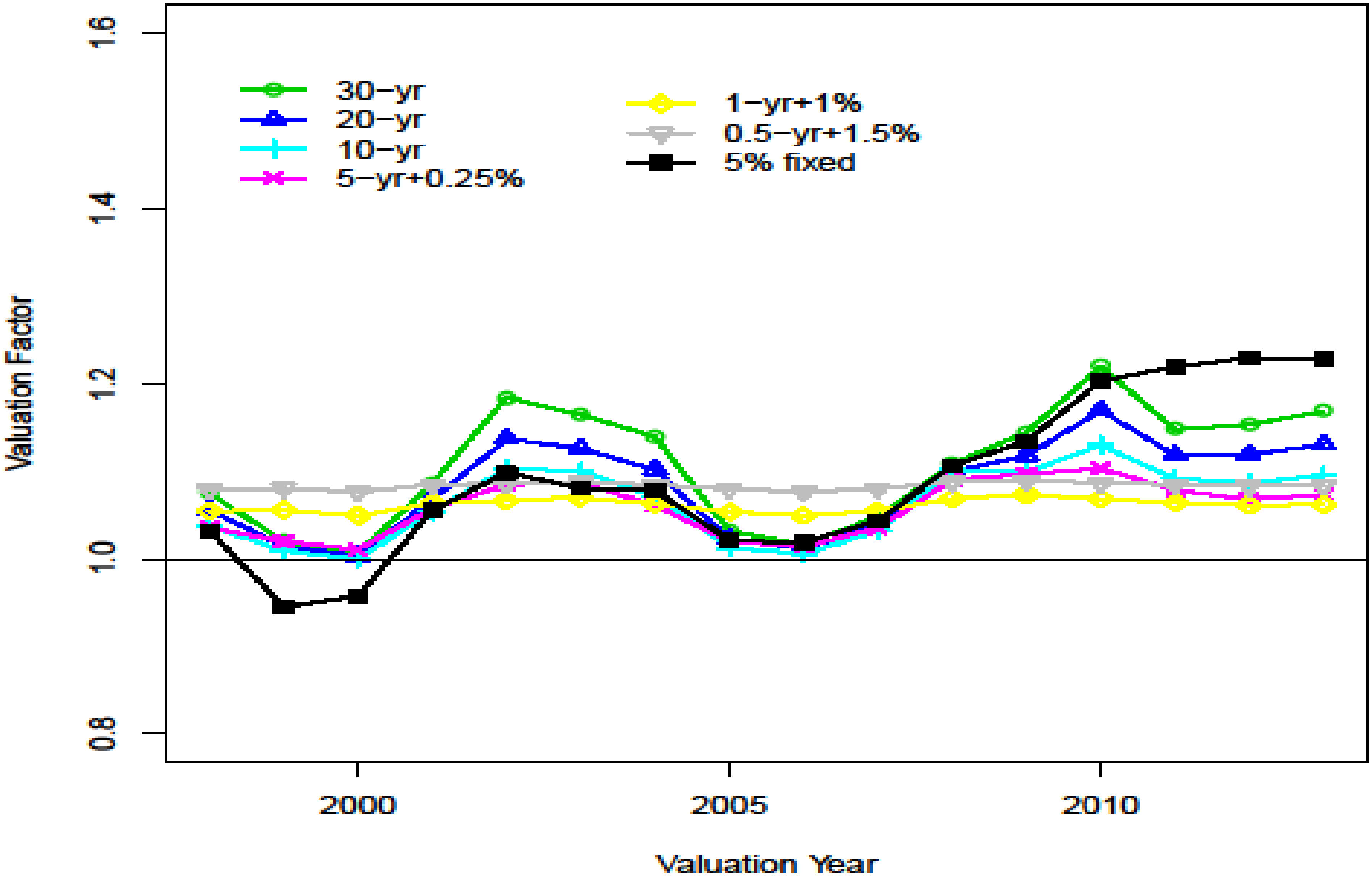
T=20-years


Valuation Factor
1.6
1.4
1.2
1.0
0.8
2000
2005
2010
Valuation Year
30−yr
20−yr
10−yr
5−yr+0.25%
1−yr+1%
0.5−yr+1.5%
5% fixed

T=10-years


30−yr
20−yr
10−yr
5−yr+0.25%
1−yr+1%
0.5−yr+1.5%
5% fixed
Valuation Factor
0.8
1.0
1.2
1.4
1.6
2000
2005
2010
Valuation Year

T=5-years


30−yr
20−yr
10−yr
5−yr+0.25%
1−yr+1%
0.5−yr+1.5%
5% fixed
Valuation Factor
0.8
1.0
1.2
1.4
1.6
2000
2005
2010
Valuation Year

Comments

- Long rates and constant rates produce more volatility than short rates.
- For fixed rates -- costs have risen through the crisis
- For market based rates – it's more complicated
  - Interest rates were high in 1999, $r_{30} \approx 6.3\%$
  - But the cost is low
  - The risk is from the spread, $r_k(t) - r(t)$ not from the absolute values

Comments

Has the cost risen since the early transitions in 1998?

- For fixed rates – yes
- For market based rates – it's more complicated
  - Interest rates were high in 1999, $r_{30} \approx 6.3\%$
  - But the cost is low because short rates were also high.
  - The risk is from the spread, $r_k(t) - r(t)$ not from the absolute values

Actuarial valuations

- Review traditional approaches
- Consider three CB methods
- Principles and notation:
  - AL_t = actuarial liability = target asset requirement
  - NC_t = Normal Contribution = contribution needed to fund the expected increase in *AL*, *t* to *t+1*
- Under valuation assumptions, ignoring exits

$$(AL_t + NC_t)(1 + i_t) = AL_{t+1}$$

Actuarial valuation for final-salary DB

- Accruals based $\Rightarrow$ past service earned benefits are included in the valuation
- Accruals methods are PUC and CUC(=TUC)
  - Projected accrued $\Rightarrow$ benefits from past service indexed to retirement by salary scale.
  - Current accrued $\Rightarrow$ benefits from past service valued assuming no further increases.

CB Valuation 1: Past service, projected credited interest

- Past service $\Rightarrow$ no allowance for future contributions to participant's fund
- This is the method used above, with market rates and models

$$AL_t = F_t\, V(t,T)$$

$$NC_t = cS_t\, V(t,T)$$

CB Valuation 2: Past service, current credited interest

- Past service $\Rightarrow$ no allowance for future contributions to participant's fund
- Current credited interest $\Rightarrow$ no allowance for future credited interest
- $v_i(s)$ denotes the valuation discount factor for s-yrs ahead

$$AL_t = F_t$$

$$NC_t = cS_t + \left(F_t + cS_t\right)\Big((1+i^c(t))v_i(1) - 1\Big)$$

CB Valuation 3: Full service, projected credited interest, pro-rata accrual

- Let $\widetilde{B_t}(T)$ denote the projected final benefit, and let n denote service at the valuation date
- Deterministic salary growth and crediting rate assumptions

$$AL_t = \left(\tilde{B}_t(T)\, v_i(T-t)\right)\frac{n}{n+T-t}$$

$$NC_t = \frac{AL_t}{n}$$

Example

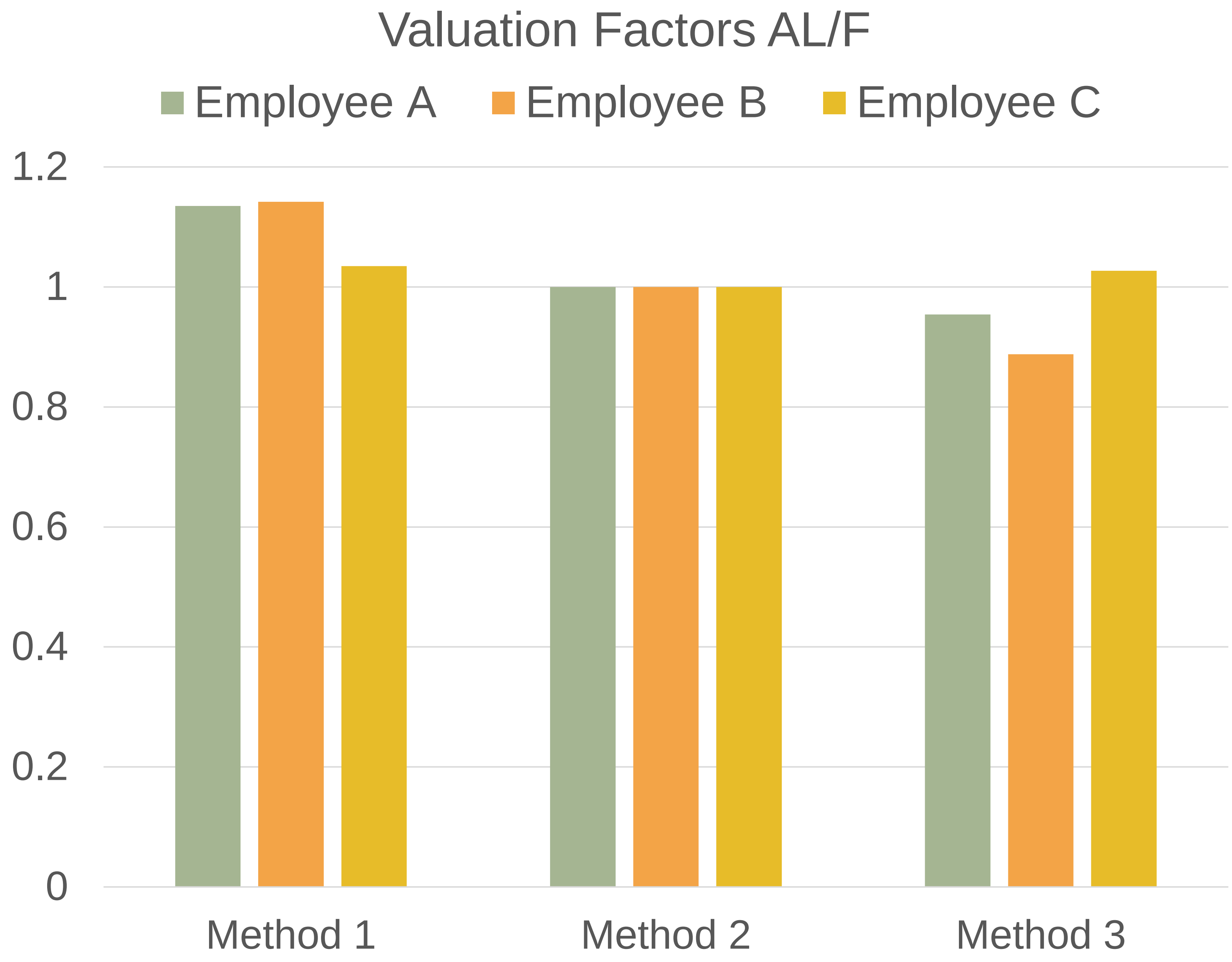
- Employee A
  - 1 year service
  - 19 years to retirement
  - S= 50 000; F= 4 000
  - c=6%
- Employee B
  - 10 years service
  - 10 years to retirement
  - S=60 000; F=55 000
  - c=6%
- Employee C
  - 19 years service
  - 1 year to retirement
  - S=75 000; F=100 000
  - c=6%

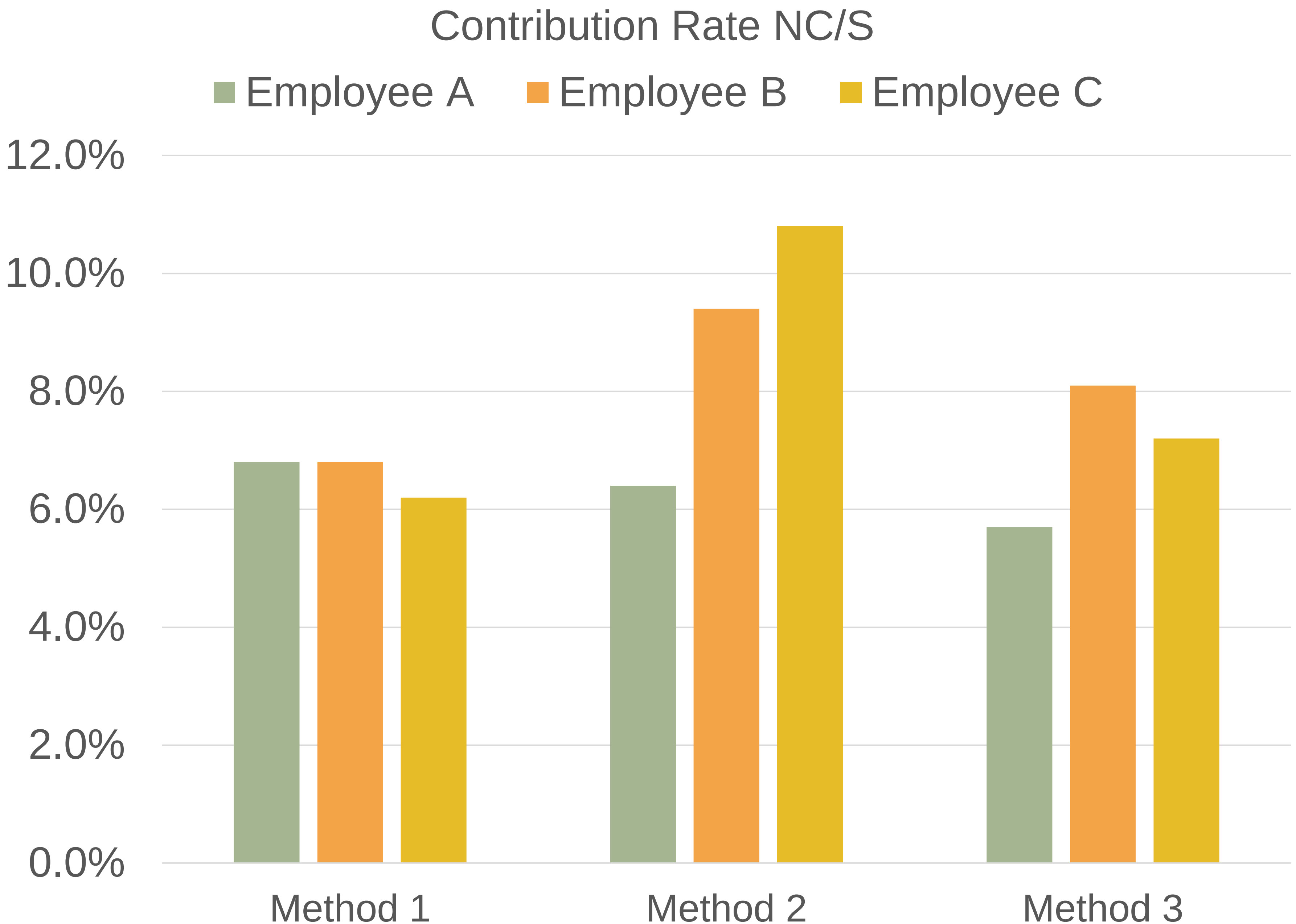
Example

- Assume Corporate Bond valuation interest rates
- Crediting rate = 0.036 (30-year rate)
- Future crediting rate assumption (for method 3)

  $i^c(s) = 0.036$

- Future salary growth assumption 2% p.y. (method 3)


Valuation Factors AL/F
Employee A
Employee B
Employee C
1.2
1
0.8
0.6
0.4
0.2
0
Method 1
Method 2
Method 3


Contribution Rate NC/S
Employee A
Employee B
Employee C
12.0%
10.0%
8.0%
6.0%
4.0%
2.0%
0.0%
Method 1
Method 2
Method 3

Comments 1

- Method 1 is a PUC method
  - Projecting benefit increases through future service period
- Method 2 is a TUC method
  - Valuation does not project future benefit increases
- Method 3 is not an accruals method
  - But is sometimes called PUC as it uses future salaries.

Comments 2

- Valuation Factors:
  - Method 1: $AL_t \geq F_t$
  - Method 2: $AL_t = F_t$
  - Method 3: $AL_t \lesseqgtr F_t$
- Contribution Rates:
  - Method 1: $NC \geq c$
  - Method 2: $NC \geq c$ ($NC \gg c$ for B and C)
  - Method 3: $NC \lesseqgtr c$

Method 3 – pro-rata projected benefits

- Method 3 is adapted from traditional DB valuation
  - Not accruals based
  - Gives perverse results
    - Inconsistent with financial theory
    - Cannot be "100% Funded" at less than aggregate notional funds
    - Implies benefit is less for stayers than leavers
  - Very sensitive to assumed salary and crediting rate assumptions
  - Not suited to CB design

Concluding thoughts

- The CB benefit isn’t as simple as we thought
- This benefit isn’t as cheap as we thought/think
- DB valuation methods do not adapt to CB
  - Needs a new approach
- Design is important
  - Short rates are more stable for crediting
  - Short rates are easier to hedge

Concluding thoughts

- Do participants understand the difference between CB and DC?
  - Significant difference in benefit security when assets < notional accounts
  - Every exiting participant diminishes the security of the remainder
  - Even for a fund which is “100% funded” under Method 3
- **There is no justification for valuation factors less than 100% under any acceptable valuation methodology.**

Final question

- Does the Cash Balance Pension really meet the objectives of sponsors or participants?
  - Costs are volatile.
  - Hedging is complex.
  - Commonly used funding methods obfuscate costs.
  - Benefit security may be significantly compromised, even for “100% Funded” plan.
  - Disadvantages of lump sum benefit design from employee perspective.

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