June 2024

Hedging the Interest Rate Exposure of Cash Balance Plans

Introduction

Many plan sponsors have responded to the increased risks and affordability challenges of traditional defined benefit plans by implementing plan designs which grant future benefit accruals based upon a cash balance formula. In a cash balance plan, the benefits provided at retirement are linked to the contributions made by the plan sponsor (and sometimes the member), accumulated up to retirement using a pre-defined crediting rate.

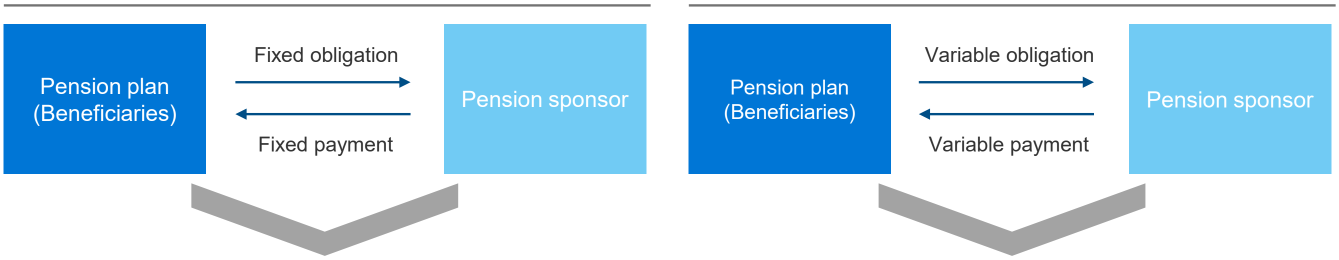
This crediting rate is typically linked to long-term interest rates, such as a 30-year par yield. This can mean that, unlike traditional defined benefit pension plans, both the benefit amounts and the liability discount rate are sensitive to changes in interest rates.

There are two main sources of complication when it comes to hedging such benefits. The first is that many cash balance plans operate with floors, such as 5%, in some of their benefit tranches.[1] As a result, the interest crediting rate (ICR) applied each year never falls below a certain level. When the par rate is below the floor rate, the ICR equals the floor rate but, when the par rate is higher than the floor rate, the effective ICR floats with the par rate.

When interest rates are low, as they were until relatively recently, liabilities are largely fixed in nature as they simply receive 5% increases each year. But now yields are much higher, and as a result, liabilities can be substantially more floating in nature. Recognizing the partially floating nature of the liabilities is important. Compared with a traditional plan that offers only fixed increases, the durations are much lower at higher interest rates. You can see this in an illustrative plan in Figure 2, calculated using the approach we will outline. This illustrative plan has 40% of benefits linked to 30-year par rate subject to a 5% floor and 60% of benefits purely fixed in nature.

Figure 1: Traditional vs. Cash balance plans

Traditional plan | **Cash balance pension plan**

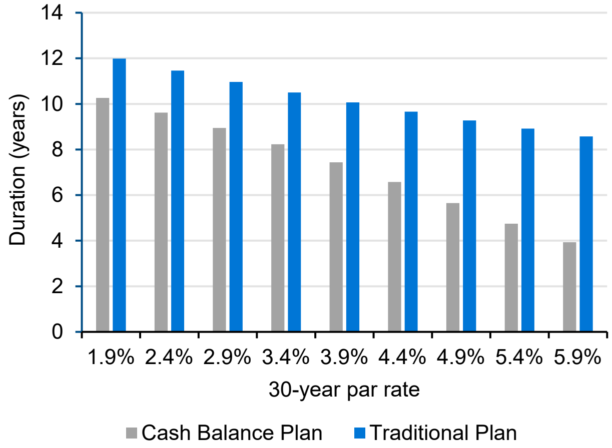


- The retirement benefits are typically based on a beneficiary's final average pay and calculated as a fixed amount at retirement.
- The calculations of benefit payment are largely depending on variable that the company control.
- They can be projected with reasonable certainty at any point in time.
- The payments are not linked, or do not vary, with the capital markets (some variability will exist from actual mortality experience).

- The retirement benefits will be based on a balance that will be available for a beneficiary at the time of retirement (or when payout is triggered).
- The calculation of benefits depend on variables that the company does not fully control and is linked to the movement in the capital markets (e.g., Treasury rates).
- They cannot be projected with certainty at any point in time.

Source: LGIM America. For illistraive purposes only.

Figure 2: Cash balance plans with floors have lower durations than traditional plans at higher rates



Source: LGIM America calculations. Data as of Dec 31, 2022.

One approach to dealing with floors, which is typical in actuarial practice, is to consider the benefits as fixed when the par rate is currently below the floor, and as floating when the par rate is above the floor. This is often called a 'binary' approach. However, a common criticism of the binary approach is that it overlooks the fact that floors have a value due to the chance they bite. From a member's perspective, a floor holds positive value because it may increase their payout at retirement. When interest rates move, the value of the floor changes – the aim should be to hedge these changes in value.

When there's a floor, the sensitivity of benefits to interest rates should never be 0% or 100% - it should be somewhere in between. The question is: what exactly it should be? This, the proportion of the liabilities that is floating, is called the delta. Given a lack of suitable interest rate derivatives to hedge long-term liabilities, the least risky way to hedge benefits is to try to use the same sensitivity in the assets as the liabilities, otherwise known as delta hedging. This approach involves holding a mixture of fixed and floating assets with the delta determined from a stochastic model.

The second complication arises from the fact that long-term interest rates, rather than short-term (cash or T-bill) rates, are used for indexation. As we shall see, this leads to complex interest rate sensitivities with respect to shifts in the yield curve.

For these reasons, the fixed income benchmarks most used for traditional defined benefit plans are inappropriate for cash balance plans in most circumstances. As such, the hurdle for introducing a customized liability benchmark for fixed income assets is substantially lower.

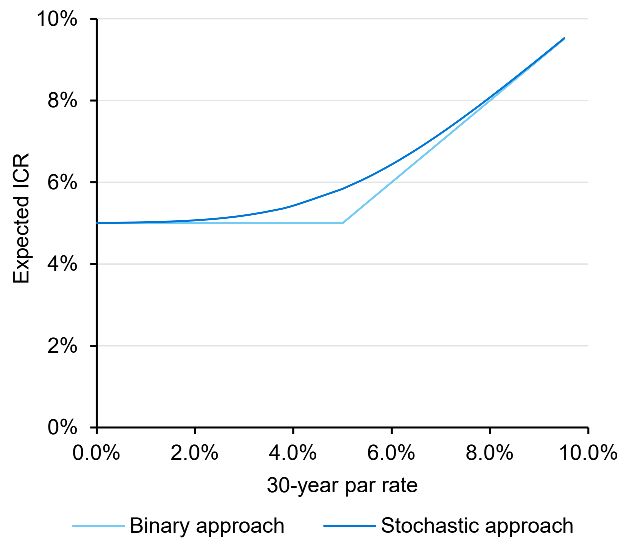
There are also some other complications with hedging liabilities that are outlined in Appendix C.

Key criticism of the binary approach

As previously mentioned, for simplicity, actuaries may not allow for optionality when performing their valuations. As a result, they may simply assume future increases at the floor if current par rates are below the floor or increases in line with the par rate if it is above the floor. From a short-term valuation perspective, it might seem appropriate to adopt a binary hedging approach (i.e., ignore the volatility of interest rates).

There are three main issues with this. The first is that liabilities will be understated. Even at higher interest rates, the floor has some value to a member since it protects their increases from falling to low levels should interest rates fall in the future. This could lead to a lack of prudence for funding purposes. Figure 3 illustrates this using a specific example.

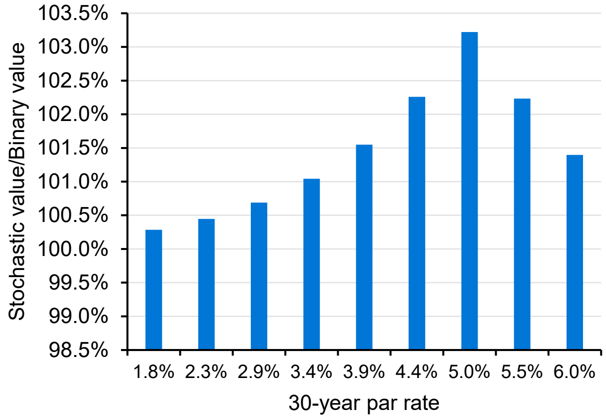
Figure 3: The expected ICR with a 5% floor is significantly higher under a stochastic approach



Source: LGIM America calculations. Assumes 2% volatility for illustration.

Figure 4 indicates how significant this could be for our illustrative cash balance plan. Using a stochastic approach results in a higher liability value compared to the binary approach. This is because the stochastic approach takes into account the volatility of interest rates, offering the possibility that the floor will enhance benefits even when interest rates are currently above the floor.

Figure 4: Liability value of a stochastic approach as a percentage of a binary approach

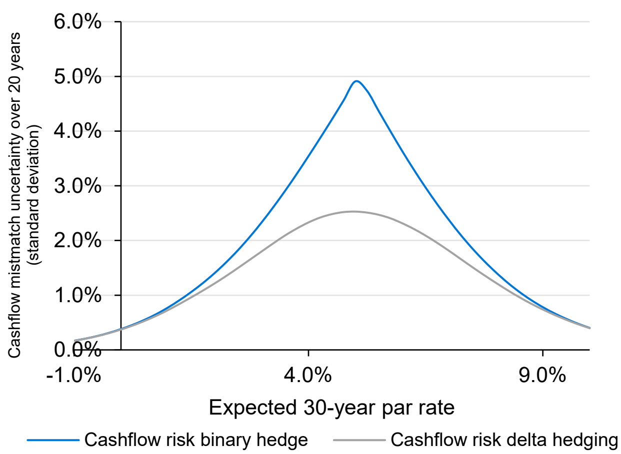


Source: LGIM America calculations. Data as of Dec 31 2022.

The second issue is that if the hedge is designed to mirror changes in the actuarial value of liabilities, it leads to a suboptimal strategy. This is not necessarily obvious, given that in the short term it may appear less risky, and more consistent, to hedge in the same way as liabilities are valued. Changes in interest rates, as opposed to increases awarded, tend to dominate moves in the near term; assets and liabilities will essentially move in line with each other in the short run. But in the long run, this risk catches up with the plan.

This becomes clear if you model the ultimate asset and liability cashflows. Figure 5 illustrates an example of this for a liability cashflow payable in 20 years that is credited in line with 30-year par rates subject to a floor of 5%. Increases are modeled stochastically in the way described in Appendix A over the 20-year period, then calculated the uncertainty of the cashflow mismatch. This is defined as the standard deviation of the asset cashflow divided by the benefit payable at year 20.

Figure 5: A 'binary' hedge almost doubles cashflow risk if interest rates are close to the floor

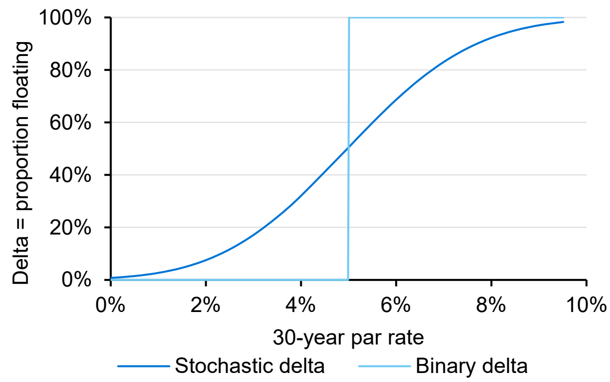


Source: LGIM America calculations. See Appendix A for assumptions.

Far away from the floor, binary and delta hedging are similar, so the impact of choosing one over the other is immaterial. But near the floor it can make a substantial difference. The model suggests a binary hedge could be around twice as risky if interest rates are near the floor. Note that neither approach is riskless because rebalancing was assumed to occur only annually in this illustration, rather than continuously.[2]

One way to understand how the binary approach is risky is to compare the delta it uses when hedging with a more realistic estimation of the delta of the liabilities.

Figure 6: A binary delta is too low at low interest rates and too high at high interest rates

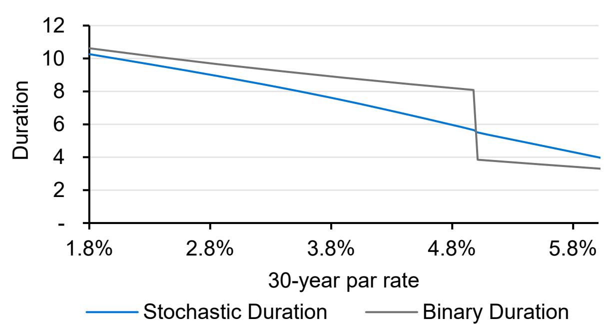


Source: LGIM America calculations. Assumes 2% volatility for illustration.

When interest rates are high, the binary approach tends to overestimate the proportion that is floating and under-hedge the PV01 (the Present Value impact on the liabilities of a one basis move in interest rates) of the liabilities. When interest rates are low, it tends to over-hedge the PV01.

Lastly, a binary hedge can suffer practical problems, such as abrupt changes in the hedge due to only a slight change in interest rates, for example, if the expected 30-year par rate moves from just below the floor to just above it.

Figure 7: The binary duration changes abruptly around the 5% floor rate



Source: LGIM America calculations for a typical cash balance plan linked to 30-year par rate and subject to a 5% floor (40% indexed to interest rates with a floor of 5% and 60% purely fixed).

Calculating an appropriate delta hedge

So, what exactly is an appropriate approach? Whilst there is no single correct answer, we believe that the LDI hedging solution should aim to reflect the true economics of the cash balance liabilities. In particular, the approach should recognize that a floor represents an additional cost to the plan, even if interest rates are currently above that floor, since members effectively own a put option that protects them against a fall in interest rates. Quantifying this cost and hedging it requires a model for the uncertainty of interest rates. The question is: what model should we use? In addition, we need to ensure that the complex sensitivity to yield curve movements that cash-balance plans are exposed to is properly addressed.

One possible approach is to calibrate a model to the prices of interest rate options, such as swaptions. This is a 'market-consistent' approach. An issue with applying this approach in general is the limited availability of quotable markets on this type of derivative instrument. A viable alternative that still recognizes the uncertainty of interest rates is a so-called 'real-world' approach. In this approach, which is outline next, the behavior of interest rates is calibrated to historical moves.

A real-world approach: four modeling steps and one bonus step

1. Split cashflows into tranches

As a first step, it is crucial to understand the different benefit tranches within the plan. For example, there could be a tranche that is purely fixed, a tranche that that is floating with a floor of 2% and another tranche with a floor of 5%. Data may already be available split by tranche. If not, and deterministic actuarial shocks are available, it is often possible to estimate the split between tranche types from those shocks.

2. Project a central case evolution of 30-year par rates

This is done by taking the forward interest rate curve – which represents the market's expectations for the evolution of short-term interest rates, rolling down the yield curve and then computing the 30-year par rate of the new curve.

3. Estimate the size of the increase in year t and their deltas

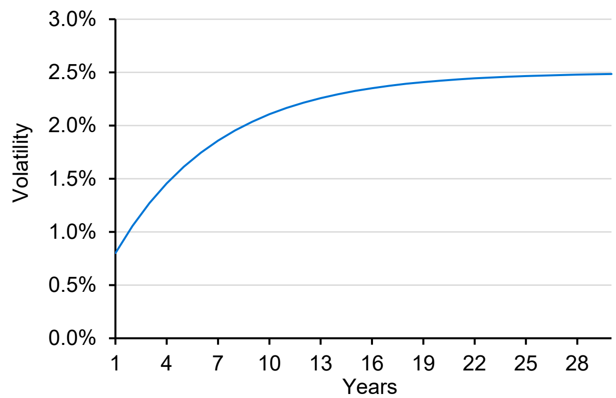
To account for the floor, we used a Black model to value increases and to calculate delta sensitivities, with the expected values taken from step two. The deltas here represent the proportion of the cashflow that is floating in nature, rather than fixed.

The Black model takes in interest rate volatility (here the volatility of the 30-year par rate) as an input. In the calculations, a higher volatility at longer horizons is used to reflect that increases are more uncertain the further away they are, rather than a single volatility number. This can be more important for interest rates than inflation because inflation tends to be more mean reverting in nature, thanks to inflation targeting by the Fed. The volatility term structure was fitted to rolling historical changes over the horizon incorporating mean reversion effects.[3] The term structure we assume is:

Forward volatility of 30-year par rate for year t = $2.5\% - 1.7\%(0.85)^{t-1}$

This is shown in Figure 8.[4]

Figure 8: Forward volatility



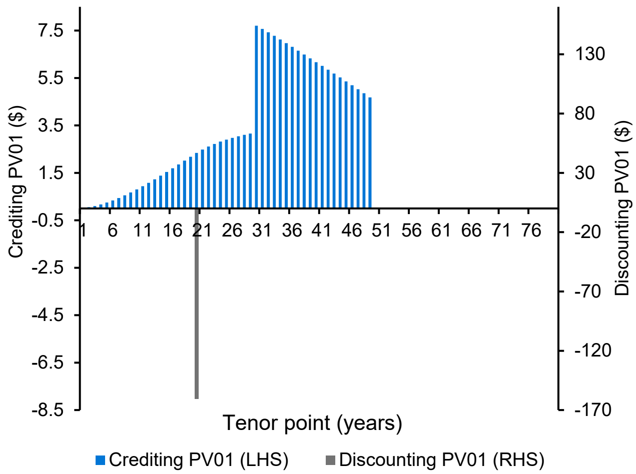
Source: LGIM America. For illustrative purposes only.

4. Allow for curve risk

Curve risk can be a curve ball. As increases are based on 30-year par rates, the sensitivity to bumps in the spot rates curve is complicated. To deal with this, a formula was derived, detailed in Appendix B, for calculating the impact of a single basis point move in the Treasury spot curve at tenor t on the expected increase rate in the absence of a floor. It was then coded as a matrix and, by computing its inverse, we were able to calculate crediting PV01 ladders quickly and efficiently. The upshot is we properly allow for sensitivity of future increases to shocks to the curve at the right tenor point. The matrix approach also allows us to hedge curve risk in a highly computationally efficient way, rather than needing to loop the model through bumps to the spot rates curve at every tenor point.

To illustrate the complexity, Figure 9 illustrates the PV01 ladders for an expected $100,000 cashflow payable in 20 years. The amount is indexed/increased in line with the 30-year par rate each year with no floor to make it simpler. An overall risk profile for an indexed tranche can be found in Appendix D.

Figure 9: PV01 ladders for a cashflow payable at time 20, indexed to 30-year par rates



Source: LGIM America. For illustrative purposes only.

The discounting PV01 in grey relates to the impacts on isolated changes in the Treasury curve spot rate on the discounting of the cashflow. In contrast, the crediting PV01 relates to isolated changes in the Treasury curve spot rate on the crediting of the cashflow.

The discounting PV01 is straightforward but the shape of the crediting PV01 ladder requires some explanation. Each year the cashflow is credited in line with a 30-year par yield. The expected future increases were calculated by rolling down the forward Treasury curve and computing what the yield on a 30-year par Treasury in each year would be.

For a tenor shorter than 30 years, say T < 30, bumping the current spot rate curve at T affects the expected 30-year par yields, and so the crediting, for the next T years. This is due to the impact of the bump on the present value of coupons in the 30-year par bonds. However, the impact is relatively limited since it doesn't involve the principal repayment. A notable change occurs at year 30, resulting in the spike you see. There is no impact from bumping the spot curve beyond year 50, as these rates cannot influence projected 30-year par yields for the next 20 years.

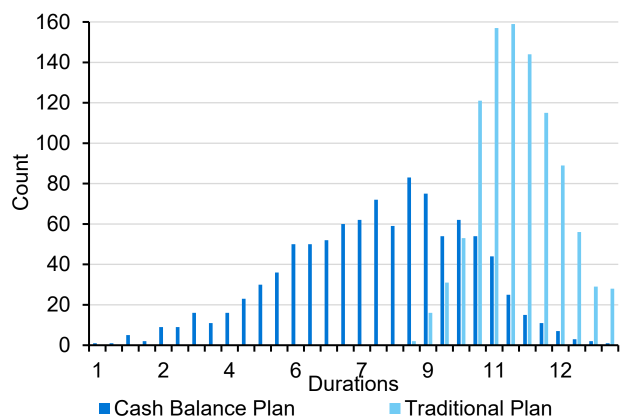
The overall PV01 (combining crediting and discounting PV01s) is close to zero, as you would expect for a benefit with floating increases. However, you can see there is considerable curve risk. For example, if the 20-year spot Treasury rate doesn't increase but the 40-year rate does, this will cause the PV of the liabilities to increase.

5. Stochastic simulation of risk ladders (optional)

Having established the current PV01 ladders of the assets and liabilities, we are able to simulate liability analytics. We can show the distribution of duration under stochastic scenarios with instantaneous shocks to yield curves (more details are provided in Appendix E).

Focusing just on the liabilities for illustration purposes is interesting. In general, the duration of a plan changes as interest rates move due to convexity effects: at higher interest rates longer-dated cashflows are discounted more relative to shorter-dated cashflows, leading to a shrinking of duration. But for cash balance plans with a floor, there is an additional impact: as interest rates rise, the benefits become more floating (as the floor is approached or exceeded), which causes an even greater shrinking of duration. This results in a much wider dispersion of possible durations in the future, as can be seen in Figure 10.

Figure 10: Duration distribution of cash balance pan and traditional plan



Source: LGIM America. Distribution of durations for our illustrative cash balance plan with 60% floating with a 5% floor and 40% purely fixed. The chart is based on 1,000 simulations. The shocks are treated as if they occur instantaneously.

This underlines the need for a dynamic and adaptive hedging strategy.

Conclusion

For plan sponsors that have introduced cash balance plans as an alternative to more traditional defined benefit plans, the challenges of hedging the interest rate sensitivities that these plans introduce are complex but solvable.

The most used market benchmarks employed by pension plans are almost wholly inappropriate for cash balance plans and can potentially increase risk rather than reduce it. On this basis, the hurdle for introducing a customized liability benchmarked strategy is substantially lower than for traditional defined benefit plans. It is recommended that plan sponsors have a strong understanding of the unique market risk exposures cash balance plans present.

We continue to believe that setting explicit interest rate and credit spread hedge ratios for cash balance plans is appropriate, and in line with our previously released research.[5]

An optimal strategy will involve a combination of credit assets to achieve the appropriate credit spread hedge (determined within a total portfolio context), Treasury securities and both long and short interest rate derivatives to match the specific key rate duration sensitivities of the cash balance plan. Other considerations may also impact the ultimate solution (as outlined in Appendix C).

In future analysis, we will explain what the hedging solutions for cash balance plans with floors could be like in practice. This includes dynamic delta hedging using fixed income instruments that we have discussed here and how often to rebalance. It will also include what dynamic delta-gamma hedging, using interest rate derivatives like swaptions, could look like.

Appendix A: Assumptions for the illustration of long run cashflow risk

The calculation assumes:

- A bullet cashflow 20 years away.
- Flat/static central case evolution of the 30-year par rate.
- Yearly rebalancing.
- The delta hedge uses the correct interest rate volatility (i.e., assumes there is no parameter uncertainty). So, if the rebalancing were continuous then delta hedging would be riskless.
- Floor of 5%.
- Volatility term structure as agreed below i.e. forward vol for year $t = 2.5\% - 1.7\%(0.85)^{t-1}$.
- Cashflow mismatching uncertainty calculated as the standard deviation of the proportion of the benefit that can ultimately be paid at time 20.

Appendix B: Closed form formula for the crediting rate sensitivity

The 30-year par yield can be calculated as:

$$\frac{1 - df_{30}}{\sum_{i=1}^{30} df_i}$$

where df_i is the discount factor at tenor i years. For a shock to the spot rate at tenor k < 30 of 0.01% the impact on the par yield is:

$$\frac{(1 - df_{30})}{(\sum_{i=1, i\neq k}^{30} df_i + df_k . e^{-k*0.01\%})} - \frac{(1 - df_{30})}{\sum_{i=1}^{30} df_i}$$

For a 0.01% shock to the 30-year spot rate, the impact on the par yield is:

$$\frac{(1 - df_{30} . e^{-30*0.01\%})}{(\sum_{i=1}^{29} df_i + df_{30} . e^{-30*0.01\%})} - \frac{(1 - df_{30})}{\sum_{i=1}^{30} df_i}$$

Appendix C: Other considerations and complexities

Lags

Often the plan construction is such that the interest crediting rate is based upon the level of Treasury yields at a fixed date prior to the crediting year due to administrative and regulatory reasons or is based upon an average level of Treasury yields over a given period. In addition, the crediting rate is typically only set once a year, and thus, as the crediting rate for that year fixes, the liability cashflows will lose some interest rate duration. Any lag or averaging in the crediting rate methodology will introduce some positive duration into the plan, as it has the effect of fixing a proportion of the cashflows. Thus, when the yield curve moves, the liability cashflows do not move to the same degree as the discount rate, which introduces a small positive level of interest rate duration. However, unless the lag or averaging periods are substantial, the impact will be minimal.

Using swaptions for floors

The delta of the assets versus that of the liabilities changes over time, especially if there is an abrupt change in interest rates. In principle, with highly frequent rebalancing this is not an issue, and the “gamma” risk can be avoided. However, another strategy is to use swaptions. For example, when floors are much higher than projected crediting rates, a potential hedging strategy is to purchase a series of payers swaptions struck at the floor at the same time as hedging liabilities as if they the same as a traditional defined benefit plan (with positive duration). The purchased payer swaptions will reduce the duration of the asset portfolio to match that of the liabilities should interest rates rise substantially. Similarly, when floors are much lower than projected crediting rates, the plan could purchase a series of receivers struck at the levels of the floor, while hedging liabilities like a cash balance plan (with no duration). The purchase of receiver swaptions will increase the duration of the asset portfolio to match that of the liabilities should interest rates fall substantially. While such a strategy may provide the optimal hedge as it removes the short gamma position, it can be extremely costly, particularly when the strike of the floor is close to the current implied crediting rates.

ABO vs PBO liabilities

PPA (funding) based approaches to liability valuations are based upon a Traditional Unit Credit cost method, like an accrued benefit obligation (ABO) valuation methodology, which only reserves for liabilities that have been earned at the valuation date. This valuation methodology is very similar to the approach that we discuss throughout the paper. For accounting disclosure measures, a Projected Unit Credit cost method which underlies the projected benefit obligation (PBO) measure is employed. The calculation of PBO involves pricing out expected benefits at retirement including the impact of future expected salary increases. With respect to the accrual method, the PBO utilizes future service post the valuation date, adjusting for the number of years of accrued service, when projecting future cash balances.

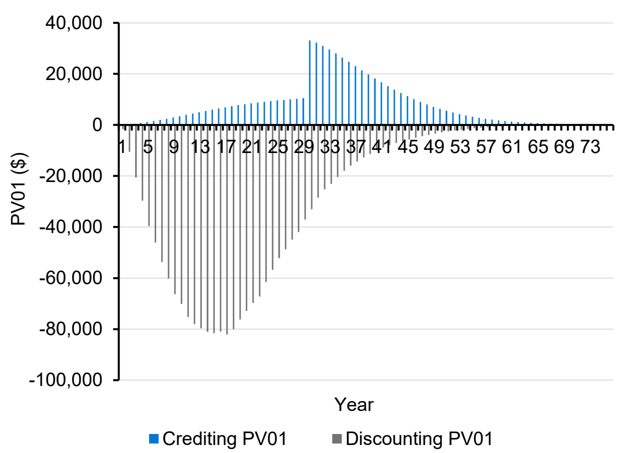
The complexities this introduces is beyond the scope of this paper, but we note that actuarially, the duration of PBO cash balance liabilities may be slightly higher than on an ABO basis due to the impact of future service accruals in the valuation process.

This complexity can be worked through with the actuary during the hedge design process.

Appendix D: Overall PV01 profile of the floating tranche

Figure 11 shows the overall PV01 profile of the floating tranche for our illustrative cash balance plan with a 5% floor.

Figure 11: Risk Ladder for a cash balance plan ICR 30-year par rate, 5% floor



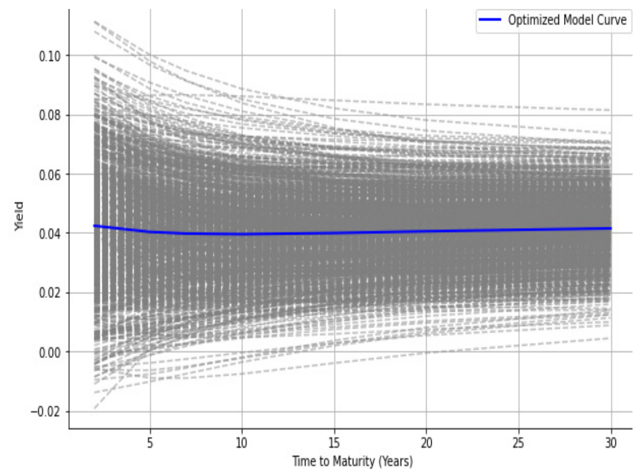
Source: LGIM America calculations for the floating tranche in an illustrative cash balance plan linked to 30-year par rate and subject to a 5% floor.

The picture combines cashflows payable at various maturities. As there is also a floor involved, the grey bars sum to more than the blue bars, reflecting that the plan is partially fixed.

Appendix E: Stochastic shock scenarios

We fitted the Nelson-Siegel Model to 20-year historical US Treasury yield curves and generated 1,000 stochastic shocks to the yield curve. These stochastic shocks capture various dynamics of the yield curve, including level, steepening and curvature.

Figure 12: Simulated yield curve based on Nelson-Siegel model



Source: LGIM America calculations. Data as of Dec 31 2022.

About LGIM America

LGIM America (LGIMA) was founded in 2006 with the purpose of helping people achieve their long-term financial goals. We offer a range of strategies to help our institutional clients (corporations, healthcare agencies, non-profit, education, public plans and Taft-Hartley) manage their investment objectives, which can range from market-based alpha-oriented strategies to those that are designed to be more liability-centric, derivative overlays, or indexed solutions. Encouraging a diverse and inclusive environment coupled with a solutions-focused culture allows us to increase our breadth of knowledge and the likelihood of improved client outcomes and stronger financial performance. We have teams of experienced, innovative professionals committed to helping plan sponsors meet their pension promises, managing investment exposures efficiently to seek enhanced returns while mitigating risks, and working to generate returns while making a positive societal difference.

For further information about LGIM America, find us at www.lgima.com

1. They typically do not contain caps.
2. There is also model risk given nobody knows what the ‘right’ model is for interest rates. However, we know the volatility of interest rates is not zero as the binary approach assumes.
3. For more details about the mean reversion effects please see this paper for a description of a stochastic model for interest rates we use for some models.
4. We note that the Black model neglects autocorrelation effects, in the sense that it assumes the value of a floor in a particular year is independent of the value in other years. In reality, interest rates are autocorrelated. However, this is not a material issue for these calculations thanks to the fact that the increases are additive to first order and autocorrelation doesn’t matter when adding. We confirmed this with simulation experiments.
5. ALM: Risk Management Solutions for Cash Balance Plans; https://www.treasuryandrisk.com/2015/03/05/risk-management-solutions-for-cash-balance-plans/

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